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FROM THE EDITOR

This year has been a bit of a blur. It's been eventful but, like many people, I've spent large chunks of it sat at my desk, working in my living room and spending too much time raiding the fridge. Sure, there are upsides to working from home, like when the weather's bad (as it is today), there's a joy in rolling out of bed, putting on something cosy and sitting at my desk with a hot drink. But the monotony of it all has wreaked havoc with my memory.

It seems I'm not alone. Recent research carried out at the University of California, Irvine, documented how those with previously brilliant autobiographical memories found that they became forgetful during the pandemic. Like drab wallpaper in a waiting room, a featureless year that's been dulled by lockdowns and restricted movement lacks the detail needed to make it memorable.

With that in mind, we thought it'd be fitting to press pause for an issue and take a look back at 2021, and hopefully inject a little colour into it. Over on p22 you'll find our guide to the breakthroughs that caught our attention over the last 12 months, while on p40 you can scour our wishlist of the year's most eye-catching (and giftable) tech. Then turn to p58 to get an insight into our collective psyches with the answers to the questions that have left us scratching our heads.

Enjoy the issue, and have a great Christmas!

Daniel Bennett, Editor

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LIAM O'DELL
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Virologist Jeremy looks at whether cold and flu viruses might hit us harder after a year of social distancing and lockdowns. →p32

HAYLEY BENNETT
Christmas doesn't need to be a time of overconsumption and consumerism. Hayley takes a look at how people around the world mark the winter solstice. →p46

DR STU FARRIMOND
As a doctor turned TV presenter for the BBC's *Inside The Factory*, Stu loves to experiment with food. This month we asked him if we could cook our turkey by dropping it from space. →p58

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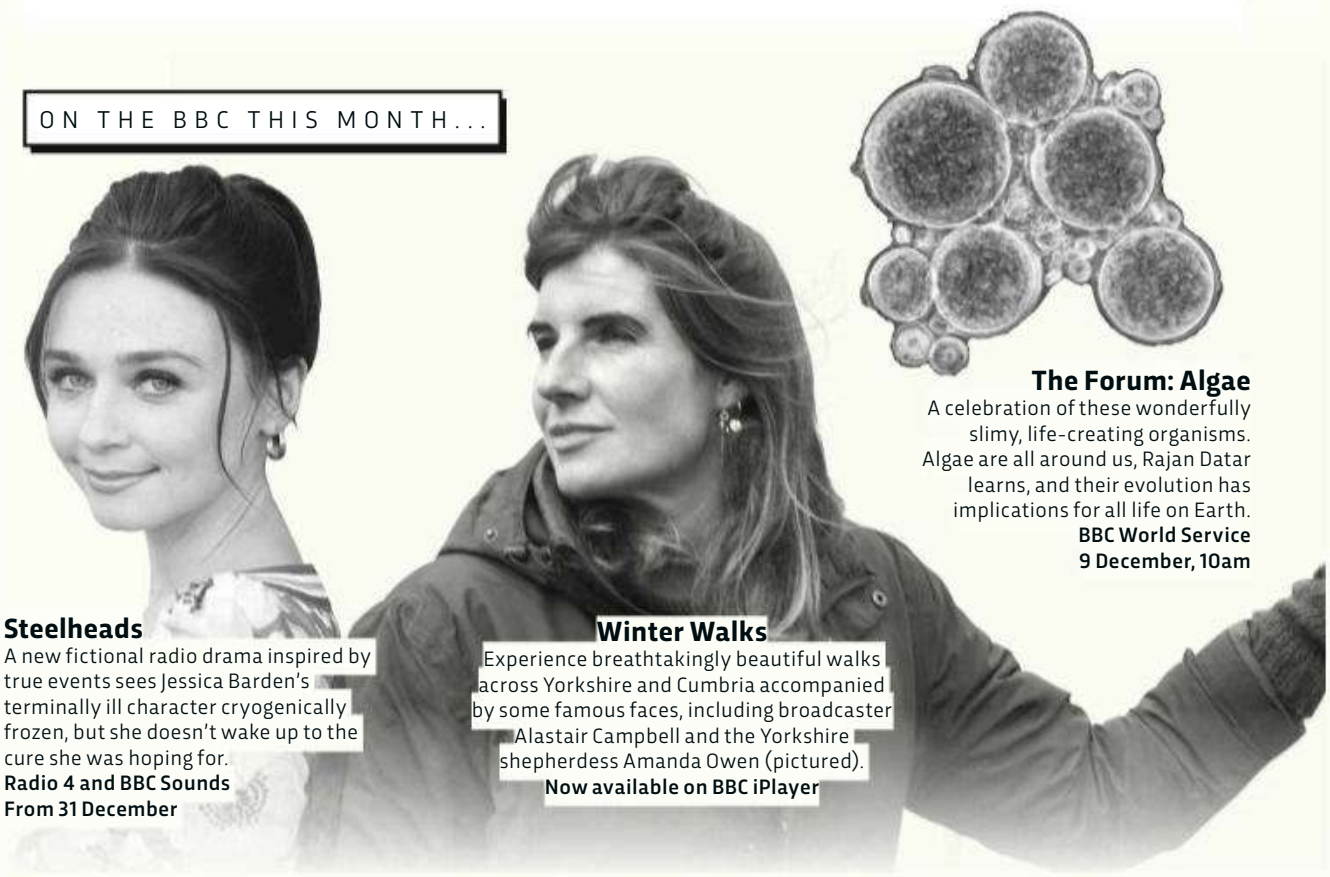

Steelheads
A new fictional radio drama inspired by true events sees Jessica Barden's terminally ill character cryogenically frozen, but she doesn't wake up to the cure she was hoping for.
Radio 4 and BBC Sounds
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Winter Walks
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Now available on BBC iPlayer

The Forum: Algae
A celebration of these wonderfully slimy, life-creating organisms. Algae are all around us, Rajan Datar learns, and their evolution has implications for all life on Earth.
BBC World Service
9 December, 10am

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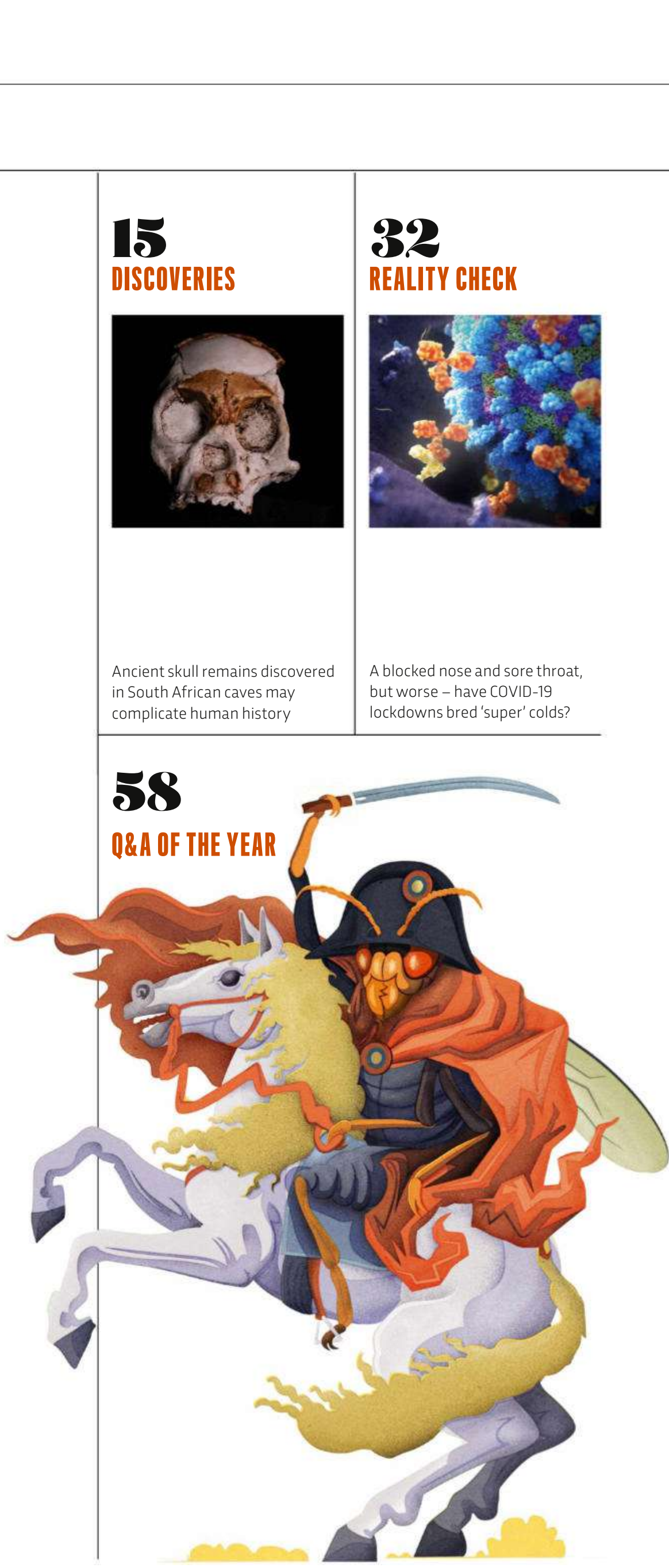

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"THERE IS A PIECE OF WORK FROM AUSTRALIA THAT LENDS SOME WEIGHT TO THE IDEA THAT SPIDERS COULD GET LARGER"

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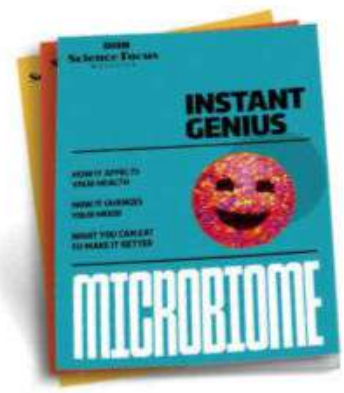

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EYE OPENER

Galaxy smash-up

NGC 5953 & NGC 5954

Captured by the Hubble Space Telescope, these two galaxies are caught in a dangerous dance that will culminate – at some point in the very, very distant future – in their merging. They're likely to have been dancing for the last billion years and it could be another billion before they become one.

"These are two galaxies having a bad day," says Prof Chris Lintott, astronomer at the University of Oxford and presenter for BBC Four's *The Sky At Night*. "Named NGC 5953 and NGC 5954, these two spiral galaxies are colliding, and you can see material from NGC 5954 being twisted and distorted by the gravitational pull of its neighbour."

While these collisions are common between smaller galaxies in the Universe, a merger of this size is "once in a lifetime," says Lintott.

We know that our own Milky Way will experience a similar collision in around five billion years' time, with our neighbouring galaxy Andromeda.

NASA/ESA/HUBBLE SPACE TELESCOPE

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EYE OPENER

Ants on the attack

LEDNICE, CZECH REPUBLIC

Here, a colony of ants swarms an unlucky hornet. Officially, they're of the species *Liometopum microcephalum*, but are more generally referred to as velvety tree ants. This is due to their soft abdomens and because they nest in hollow areas of live trees, explains Dr Douglas Booher, an ant expert at Yale University.

These ants are omnivores, and when foraging have been found travelling up to 70 metres from their nest in the hollow of a tree.

"It is not uncommon for them to hunt larger live prey, and when they do they will aggressively swarm. They have strong mandibles – making them good at [killing] – but in this case it's likely the hornet was scavenged dead, or was dying and unable to escape," says Booher.

While the ants don't sting, they can be aggressive, Booher warns. "They will swarm quickly if their nest is disturbed, and they have an obnoxious-smelling alarm pheromone with a scent like rotten coconut."

PETR BAMBOUSEK/CUPOTY03

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EYE OPENER

Launch in 3, 2, 1...

FLORIDA, USA

NASA's Moon rocket and spacecraft are nearly ready to launch.

The rocket is the new Space Launch System (SLS), NASA's most powerful launch vehicle, designed to take humans, cargo and robotic equipment to the Moon and beyond.

Atop the SLS sits the Orion spacecraft. Orion was built with deep-space exploration in mind, able to carry four astronauts to distant planets and keep them safe during missions and on re-entry.

Now, just a series of tests and a 'wet dress rehearsal' stands between the craft and the Moon.

The first launch – likely to be in February 2022 – will mark the start of many missions under NASA's Artemis programme, created to take us back to the Moon. In its 'new era of space exploration', NASA plans to set up a base camp on the Moon's surface, as well as build 'Gateway', an outpost in lunar orbit.

Artemis will also act as a stepping stone for our next giant leap — the human exploration of Mars.

GETTY IMAGES

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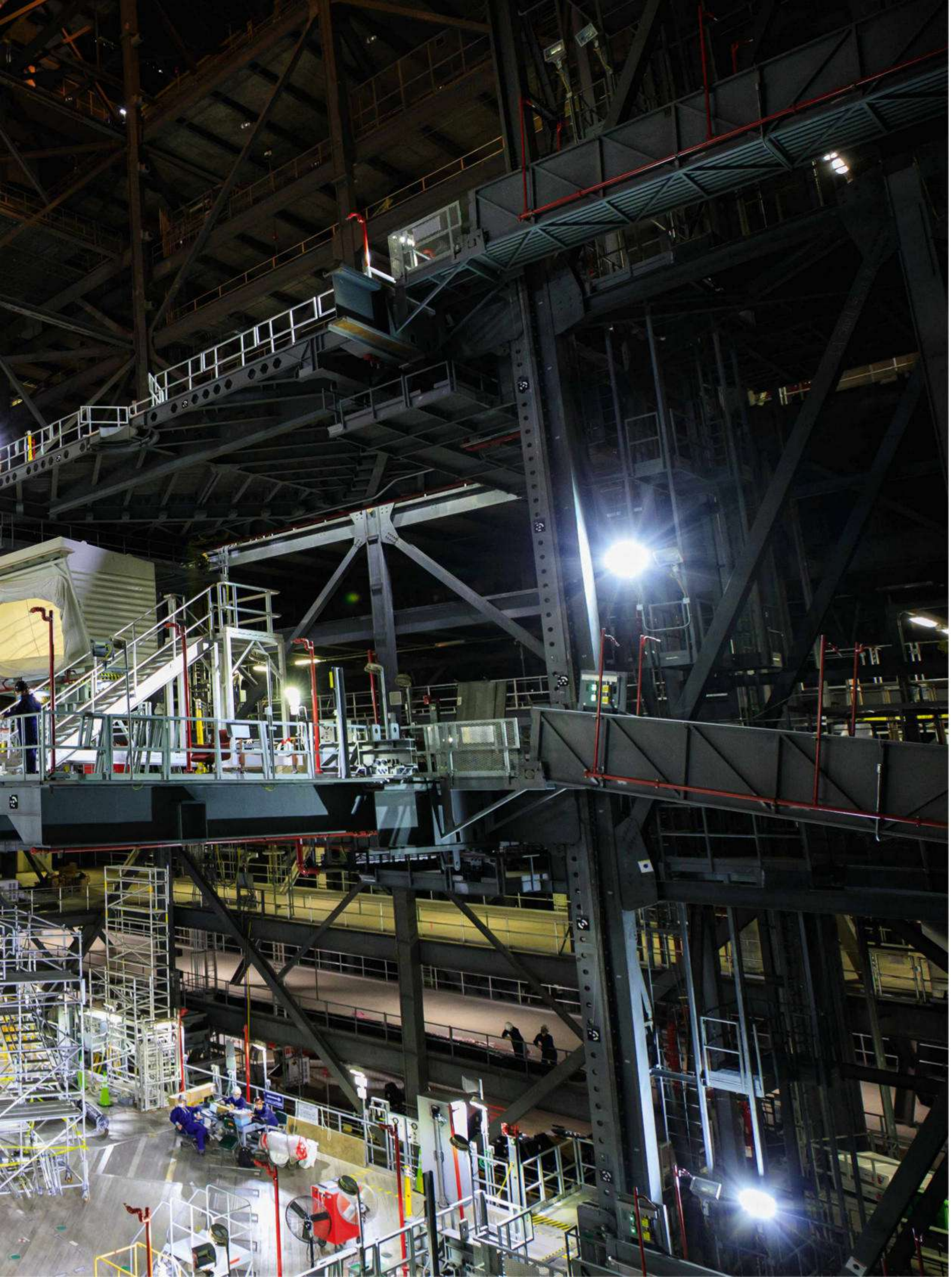

CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND *BBC SCIENCE FOCUS*

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LETTER OF THE MONTH

A deep message

Thank you for consistently combining the innovative, dynamic worlds of science and technology together exceptionally. Personally, I have been truly inspired, amazed and enthused by your magazine since I was a young engineer. The inspiration, knowledge and forward-thinking dynamics of the magazine have allowed me to achieve many great things so far, in a career that is flourishing every day and expanding to new levels.

I trained in the Royal Navy as an engineer, in the field of reactor physics and nuclear chemistry, and then embarked on an eight-year journey, exploring the world of submarines. Having spent a collective time of one full year under the waves of the planet's oceans, I always had *BBC Science Focus* magazines to keep me thoroughly absorbed and motivated.

Whether or not this email will reach the dizzy heights of your attention, may I just send my gratitude, appreciation and respect for all the hard work that is carried out behind the scenes of what is undoubtedly the best magazine in the world! My monthly subscription is only a small contributory amount compared to the running costs of the publication. However the weight in value for me far outweighs the financial aspect.

'Run silent, run deep' (submariners' motto).

John W R Gilchrist

WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins **Diesel True wireless earbuds.** The earbuds come equipped with Bluetooth 5.0 to link up to your devices, and have a total playtime of 32 hours. Plus, they are sweat- and splash-resistant, so should survive a trip to the gym. When you're not using them, keep them safe in the charging case, which is equipped with wireless charging tech as well as USB-C. **ukdiesel.com**

Units of confusion

The *Eye Opener* covering the International Space Station's new solar arrays (November, p6) conflated power and energy when describing the power boost to 215kW (peak) power the arrays would deliver.

Assuming that the ISS spends half its orbit in sunshine, the combined power means that the solar arrays could produce around 2,500kWh of energy each day. This is not far short of the annual electricity consumption of an average home.

Robin Morris

Bugging me

I enjoyed the insect apocalypse interview with Prof Dave Goulson (October, p68). However, the reason that car windscreens do not get covered in dead insects is not necessarily due to falling numbers of insects, but more to do with the aerodynamic nature of cars. My son, who drives a traditional Land Rover Defender, says he has the same problem as he always has, and has to clear the windscreen on a long journey.

Geoffrey Johnstone

Do you still get lots of splatted bugs on your car when you go for a drive?

"SEEING YOURSELF WHILE ON A CONFERENCE CALL IS DISTRACTING AND TIRING. STUDIES HAVE SHOWN THAT WHEN YOU CAN SEE YOURSELF YOU BECOME MUCH MORE SELF-CRITICAL"

DR MICHAEL MOSLEY, P55

Upgraded solar arrays should provide the International Space Station with more power

GETTY IMAGES, OCEANTHERM

During the interview, Prof Dave Goulson told me that Kent Wildlife Trust did a study where they recruited volunteers with cars of different ages to record the number of bug splats on them. They found that even people driving classic cars that are much less aerodynamic didn't have splats on them either. It's clearly a complex issue!
Alice Lipscombe-Southwell, managing editor

Me, me, me

I found Dr Julia Shaw's piece on narcissism in the October issue (p32) really thought-provoking. It made me consider the difference between narcissism and selfishness. Most definitions of narcissism mention an inflated ego and an infatuation with one's self image, but don't include disregarding others' feelings. Whereas being selfish is described as caring about yourself rather than other people.

Therefore, can people be 'high' on narcissism and still have empathy? A study conducted by the University of Michigan involving around 14,000 students found that we are 40 per cent less empathetic now than in the 1980s. This number is similar to Prof Jean Twenge's findings that narcissism levels rose by 30 per cent in US college students between 1979 and 2006. This suggests that there is a correlation between the two qualities.
Katie Welply

I'm glad you enjoyed the piece! As mentioned in the article, there are different kinds of narcissism, one of which is grandiose narcissism, in which individuals have 'disrespect for the needs of others'. Could someone be aware of others' needs, but still have disrespect for them? Probably! I would be wary of seeing correlation between two separate statistics, though.
Amy Barrett, editorial assistant

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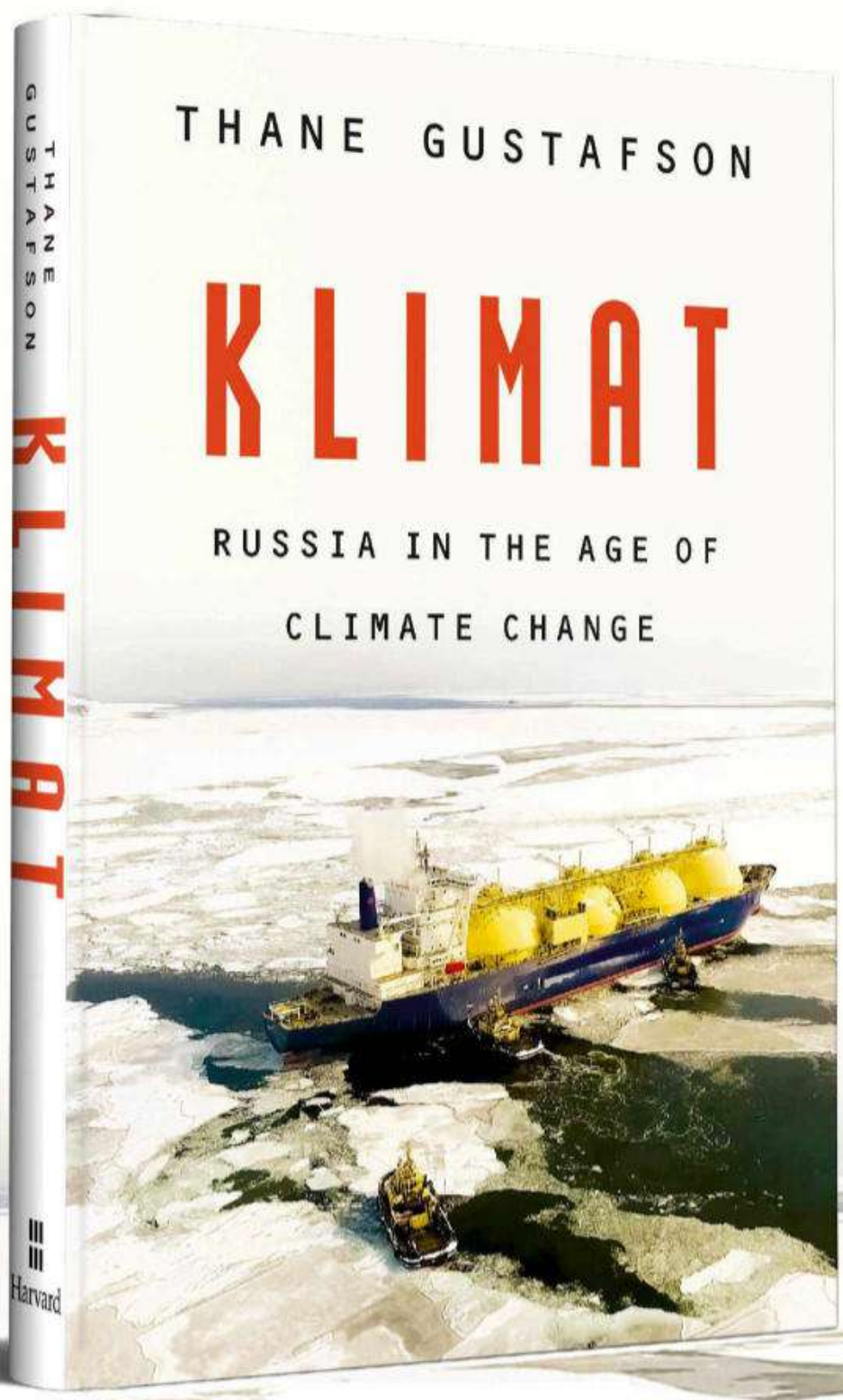
—Francis Fukuyama, author of *Identity*



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AI helps develop universal vaccines p21

DISCOVERIES

Reconstruction of the skull of *Homo naledi.* The dark areas are inferred portions of the skull

SHUTTERSTOCK

ANTHROPOLOGY

SKULL FROM ANCIENT HUMAN ANCESTOR UNEARTHED

The 250,000-year-old remains of a *Homo naledi* were found in the remote depths of the Rising Star cave system in Johannesburg

2021 in Science Our pick of the year's biggest stories from the world of science and technology p22

Prof Lee Berger with a life-sized reconstruction of the skull of Leti, a *Homo naledi* child

The partial skull of a young *Homo naledi*, an extinct species of hominin that lies within the *Homo* family tree but on a different branch to modern humans, has been discovered in South Africa. It's the first time that a child of this species has been found.

The remains were discovered around 12 metres beyond the Dinaledi Chamber in the Rising Star cave system – a complex 2km-long network of passageways and the original site of discovery of the first *H. naledi* remains in 2015. They are thought to belong to a child aged between four and six who died almost 250,000 years ago.

"*Homo naledi* remains one of the most enigmatic ancient human relatives ever discovered," said Prof Lee Berger, project leader and director of the Centre for Exploration of the Deep Human Journey at Wits University, and an Explorer at Large for the National Geographic Society.

"It is clearly a primitive species, existing at a time when previously we thought only modern humans were in Africa. Its very presence at that time and in this place complexifies our understanding of who did what first concerning the invention of complex stone tool cultures and even ritual practices."

The researchers have named the skull Leti, which means 'the lost one' in Setswana, one of South Africa's 11 official languages. It was reconstructed from 28 skull fragments and six teeth and joins almost 2,000 other individual fragments belonging to more than 20 *H. naledi* individuals unearthed in the Rising Star cave system since its discovery in 2013.

"This makes it the richest site for fossil hominins on the continent of Africa and makes *H. naledi* one of the best-known ancient hominin species ever discovered," said John Hawks,

"It is likely that other members of its species transported it to such a remote location"

a biological anthropologist and lead author of a previous study on the fossil skeleton of a male *H. naledi*, nicknamed 'Neo', that was also found at the cave.

Leti's remains were discovered in a claustrophobically tight passage that measures just 15 x 80cm. Although the skull was found in many fragments, there are no obvious signs of injury, so the researchers are unable to speculate on how Leti died.

There are also no signs of damage from carnivores or scavengers and no evidence of the skull being washed into the narrow passage by flowing water. This makes it likely that other members of its species were involved in transporting it to such a remote location.

"The discovery of a single skull of a child, in such a remote location within the cave system, adds mystery as to how these many remains came to be in these remote, dark spaces of the Rising Star cave system," said Berger. "It is just another riddle among many that surround this fascinating extinct human relative."

The researchers now plan to continue to explore the cave system and hope that any new discoveries will enable them to shed further light on whether these chambers are in fact a burial ground of *H. naledi*.

ANIMALS

Scientists discover why dogs tilt their heads

Research has shown that 'genius' dogs who can learn lots of instructions often tilt their head when they hear their owners speak

Some genius dogs can learn the names of more than 100 toys, new research has found. Those that can pass the toy test – understanding the names of two or more of their favourite playthings and retrieving them on request – are so-called 'gifted word learner dogs'.

These gifted dogs have helped researchers to understand a behaviour that has never previously been studied: the head tilt. Much like humans have a preference for one side of their body, dogs exhibit a preferred paw or nostril. These asymmetric behaviours include tilting the head, but until now, it's been unclear when and why it happens.

New research, published in the *Animal Cognition* journal, suggests that dogs tilt their head when they process something meaningful, or when they expect to be told something important.

"There are some studies suggesting that tilting the head could be a health-related problem," said Dr Andrea Sommese, lead author of the new study and researcher at Eötvös Loránd University, Hungary. "But it didn't seem likely, because we saw dogs doing it randomly and I'm pretty sure you've seen a dog tilting its head – it's very common behaviour!"

Sommese and the team at the Family Dog Project, a research centre studying the behaviour of dogs, set out to understand head tilting with a group of 'genius' dogs that they'd worked with on a previous study. This involved 40 dogs and their owners undergoing three months of training to see if the dogs could learn the names of their toys.

"We asked each of the owners to play with the dogs using two toys, and to tell the dogs the names of the toys as much as possible. After this intensive three months' training, we saw 33 of the dogs weren't able to learn the difference between the two toys – we called these the 'typical' dogs.

"But the other dogs, during this time, they didn't just learn the two toys, they learned 10, 20, 30. Our so-called 'best dog' knows the name of 160 toys or something."

There was a steep difference, Sommese explained. Either a dog learned a lot of different toys, or none. However, Sommese stressed that he's not saying dogs that can't learn toy names aren't clever in other ways.

"We think that learning words is like a talent. In humans there are people that are better at music or math or art – it seems that there is the same kind of thing going on for dogs. Some dogs are particularly skilled in this, but it doesn't mean that they're smarter. They just have one unique talent, as much as other dogs are better at sniffing or better at hunting."

After the experiment, the researchers noticed that the gifted dogs would tilt their head nearly every time their owner asked them to fetch a particular toy.

"Because we knew for sure that they know the name of some of their toys, we thought that it was something meaningful and important for the dog that made it tilt its head. It seemed to be as if the dog was saying, 'Okay, now I'm focused, I'm concentrated on the task.'"

The team initially thought it was to do with a dog's hearing, the way we might turn our head to face a person speaking in order to hear them better. But they quickly noticed that the dogs showed a preference for which side their head tilted, regardless of the position of the owner.

"It's not that typical dogs don't tilt their heads," Sommese explained. "I observed this behaviour with my own dog. It's just that we don't know what's meaningful for them and why."

The group of genius dogs present a unique opportunity for study, Sommese said. Though researchers know dogs process language in a similar way to humans, we don't really understand what language means for them.

"That's why we are so stoked to have these gifted word learner dogs, because we are getting closer and closer to finding some answers."

Think your dog is a genius? Head to Genius Dog Challenge at ***geniusdogchallenge.com*** *and share videos of your pup so that the team can confirm if you have a gifted word learner!*

Dogs seem to tilt their heads when processing something important

GETTY IMAGES X2

SPACE

Starbase, Texas: Elon Musk's plans to build the city of the future

If successful, the ambitious spaceport could become the site of multiple launches to the Moon and Mars

Elon Musk has made no secret of his intention to found a settlement on Mars, but his latest venture is to establish a city on Earth. Sited around SpaceX's launch site at Boca Chica, in Cameron County, south Texas, Musk's idea is to call the city 'Starbase, Texas'. It would house all those who work at the launch site, those who intend to launch from it, and be a tourist destination for people wanting to witness the awesome power of a launch.

Eventually, Musk hopes, it will be the point of departure for people travelling to Mars, with each mighty 'Starship' vehicle capable of transporting around 100 people at a time to the Red Planet. As they prepare for their flight, they will require the kind of living space and infrastructure that only a town or city can provide. Hence, transforming the village of Boca Chica into the city of Starbase, Texas, may be essential for Musk to realise his vision of space exploration.

Musk began the process of establishing his city in late February/early March 2021 when he officially approached Cameron County's administration. A press release from the county judge's office made it clear that Musk was to abide by all relevant statutes and that any application would ultimately be judged against applicable laws.

SpaceX announced its intention to build a launch facility at Boca Chica Village, on the US Gulf Coast, in 2014. This was following an extensive environmental assessment conducted by the US Federal Aviation Authority. Whereas Musk launches his Falcon rockets at sites leased from NASA and the US government, the Boca Chica site is owned by SpaceX. It is right next to the village of Boca Chica and while most residents sold up to SpaceX and moved away, a few refused the deal. Rather controversially, they must now temporarily evacuate their homes whenever there is a launch – and there are many launches being planned.

Boca Chica is the home of Musk's most audacious space vehicle, the Starship, along with the giant rocket, called Super Heavy, that will launch it into space. It is unlike anything ever attempted before and upon completion, will be the most powerful rocket ever launched.

"It's a really ambitious project," says Josh Barker, from the National Space Centre in Leicester. "It ties into how SpaceX got to where they are, I think they're not afraid to try things."

As a result, SpaceX is ahead of the curve. Unlike the small crew capsules that space agencies have traditionally used, Starship is a next-generation design. Standing 50 metres tall and 9 metres in diameter, much of its internal space will be living quarters, or converted to carry cargo. The Super Heavy rocket is 70 metres tall, and will be powered initially by 29 Raptor engines, which are also manufactured by SpaceX in Texas.

Stacked one on top of the other, Starship and the Super Heavy rocket reach almost 120 metres in height, almost 10 metres taller than the Saturn V rockets that NASA used to launch astronauts to the Moon in the late-1960s and early-1970s. It will be capable of generating almost twice the thrust of the NASA Moon rocket. Unlike the Saturn V, which was a single-use spacecraft, everything about Starship and Super Heavy is reusable. Both parts land

SHUTTERSTOCK

> "Unlike the Saturn V, which was a single-use spacecraft, everything about Starship and the Super Heavy rocket is reusable"

> “Starbase is undoubtedly set to become one of the most important launch sites on Earth”

vertically back on the launch pad at the end of the mission.

The launch site’s pace of development has been extraordinarily fast. Major construction work began in earnest in 2016, and the place became ready for test launches in 2019. Such accelerated progress has become something of a trademark for SpaceX, with Musk himself appearing to be a driven individual.

“I think he works his staff very, very hard,” says Barker. “He’s got a very strong work ethic and I think he demands that of his staff as well.”

The first major test flight at Boca Chica took place in December 2020, when a Starship launched into the air to test the vertical landing system. Despite getting off to a good start, it exploded when it came back into contact with the pad. Four more test flights were needed, before a Starship successfully touched down on 5 May 2021. If the previous tests proved anything, it was how robust the launch site was to explosive mishaps.

SpaceX began referring to the Boca Chica site as Starbase back in March and is now getting ready to launch its first orbital test flight of the Starship and Super Heavy combination.

It has taken the company around 16 months of additional construction to prepare an orbital launch pad at the site. This includes a ‘launch table’ for the Super Heavy to sit on, a launch tower that will lift the Starship onto the Super Heavy and hold the giant rocket in place before ignition, and a ‘tank farm’ containing fuel and other liquids that will be pumped to the rocket before launch. A set of giant ‘arms’ have also been attached to the tower. Known as ‘Mechazilla’ they will literally catch the returning Super Heavy rocket and stabilise it as it makes its soft landing back on the pad.

Regardless of whether Musk’s plans to incorporate a city close to the launch site are given the go-ahead, Starbase is undoubtedly set to become one of the most important launch sites on Earth. This is because NASA has selected Starship to be the lunar lander in its Artemis program, so it is from here that the spacecraft that will return astronauts to the Moon will launch.

Although the astronauts will launch from Cape Canaveral, Florida, the Orion crew capsule they will be in will not be equipped to land on the lunar surface. Instead, an uncrewed Starship will be launched in advance from Boca Chica and be placed into a parking orbit around the Moon. It will await the arrival of the Orion capsule, dock with it, and allow the astronauts to transfer over. Then they will pilot the Starship down to the Moon’s surface and back again when the mission is done.

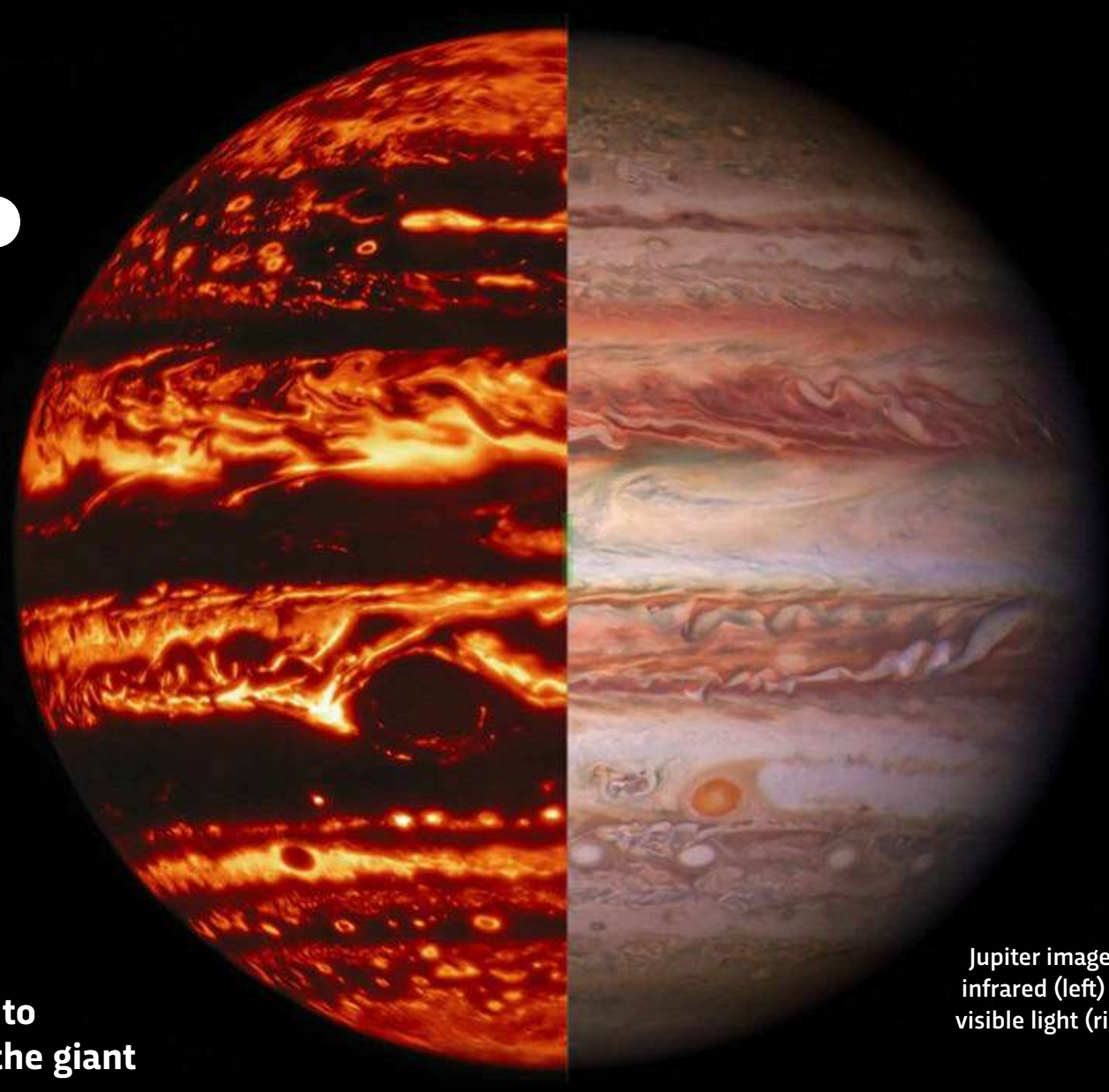
It will form a dress rehearsal of sorts for Musk’s eventual aim of Martian exploration. And even though it still sounds like science fiction, Barker thinks we should not underestimate Musk’s ambition to reach the Red Planet.

“We’ve seen that Elon can get things done. He has the drive to do it. I think there is a good chance that he will,” he says, before adding, “Or it will ruin him. And that’ll be the end of it.”

DR STUART CLARK
Stuart is an astronomy writer with a PhD in astrophysics.

SPACE

NASA's Juno spacecraft probes the depths of Jupiter's Great Red Spot



Jupiter imaged in infrared (left) and visible light (right)

The iconic storm stretches down to between 350 and 500km below the giant planet's swirling clouds

Since entering Jupiter's orbit in 2016, NASA's Juno spacecraft has completed 37 flybys of the giant planet, shedding light on the unseen processes raging beneath its clouds with each pass.

Now, scientists studying data taken by the spacecraft's microwave radiometer (MWR) and NASA's Earth-based Deep Space Network tracking antenna have made new insights into the structure of one of Jupiter's most iconic features, the Great Red Spot. With its bright crimson hue and diameter wider than the Earth, this enigmatic anticyclone has captured the imagination of astronomers since its discovery two centuries ago.

Data from the MWR shows that cyclones – large-scale air masses that rotate anticlockwise around a centre of low atmospheric pressure – within the giant planet's atmosphere in the northern hemisphere are warmer near the top and colder near the bottom. While anticyclones, such as the Great Red Spot, rotate in the opposite direction and are colder at the top but warmer at the bottom.

The findings also indicate these storms are far taller than expected, with some extending 100 kilometres below the cloud tops and others, including the Great Red Spot, reaching more than 350 kilometres.

"Previously, Juno surprised us with hints that phenomena in Jupiter's atmosphere went deeper than expected," said Dr Scott Bolton, principal investigator of Juno from the Southwest Research Institute in San Antonio, Texas. "Now, we're starting to put all these individual pieces together and getting our first real understanding of how Jupiter's beautiful and violent atmosphere works – in 3D."

> "We are getting our first understanding of how Jupiter's beautiful, violent atmosphere works"

A second team of researchers then used data on Jupiter's gravity field recorded by NASA's Earth-based Deep Space Network tracking antenna to produce a second estimate of the Great Red Spot's depth. As the Great Red Spot is so large, Juno can feel small gravitational tugs as it flies over it. By measuring tiny changes in Juno's velocity as small as 0.01 millimetre per second due to the changes in gravitational pull, the team produced an estimate of the Great Red Spot's depth of around 500 kilometres. When combined with the MWR data, this suggests the anticyclone is between 350 and 500 kilometres deep.

"The precision required to get the Great Red Spot's gravity during the July 2019 flyby is staggering," said lead author Dr Marzia Parisi, a Juno scientist from NASA's Jet Propulsion Laboratory in southern California. "Being able to complement MWR's finding on the depth gives us great confidence that future gravity experiments at Jupiter will yield equally intriguing results."

NASA/JPL, GETTY IMAGES

HEALTH

AI tool may help develop universal vaccines capable of combatting virus variants before they emerge

The technology could be used to create universal vaccines for COVID, malaria and more, its creators say

According to the World Health Organization, immunisation currently prevents four to five million deaths every year. However, an additional 1.5 million deaths could be avoided through the use of more effective vaccines.

Vaccines work by training the immune system to respond to infection by a specific pathogen, such as a virus, parasite or bacteria. At the heart of every vaccine is an antigen – a small, safe molecule based on part of the pathogen, which triggers the protective immune response.

However, most vaccine antigens are based on a single pathogen component, such as the spike protein of the COVID SARS-CoV-2 virus, which limits their effectiveness and ability to cope with new variants.

Now, Oxford-based biotech start-up Baseimmune has developed an algorithm-based system capable of creating antigens containing all the parts of the pathogen. The technology could help researchers to develop the next generation of universal vaccines that protect against future variants that could evolve in several major diseases.

"The major problem with current vaccines is that they aren't designed to account for the evolutionary arms race that occurs between pathogens and the human immune system, and can't protect against future variants or new mutations," said co-founder and software engineer Phillip Kemlo.

"Our prediction algorithm addresses all of these challenges, accelerating the creation of vaccines that are as good as they possibly can be and will stand up to whatever variants may come in the future."

Baseimmune's vaccine design algorithm draws on genomic, epidemiological, immunological, clinical and evolutionary data to create blueprints for antigens capable of responding to a particular pathogen in its current form as well as likely variants that may arise in the future.

Back in January 2020, the Baseimmune team fed the small amount of existing data about SARS-CoV-2 into their algorithm, which correctly predicted major variants such as Alpha and Delta that would not emerge for another year.

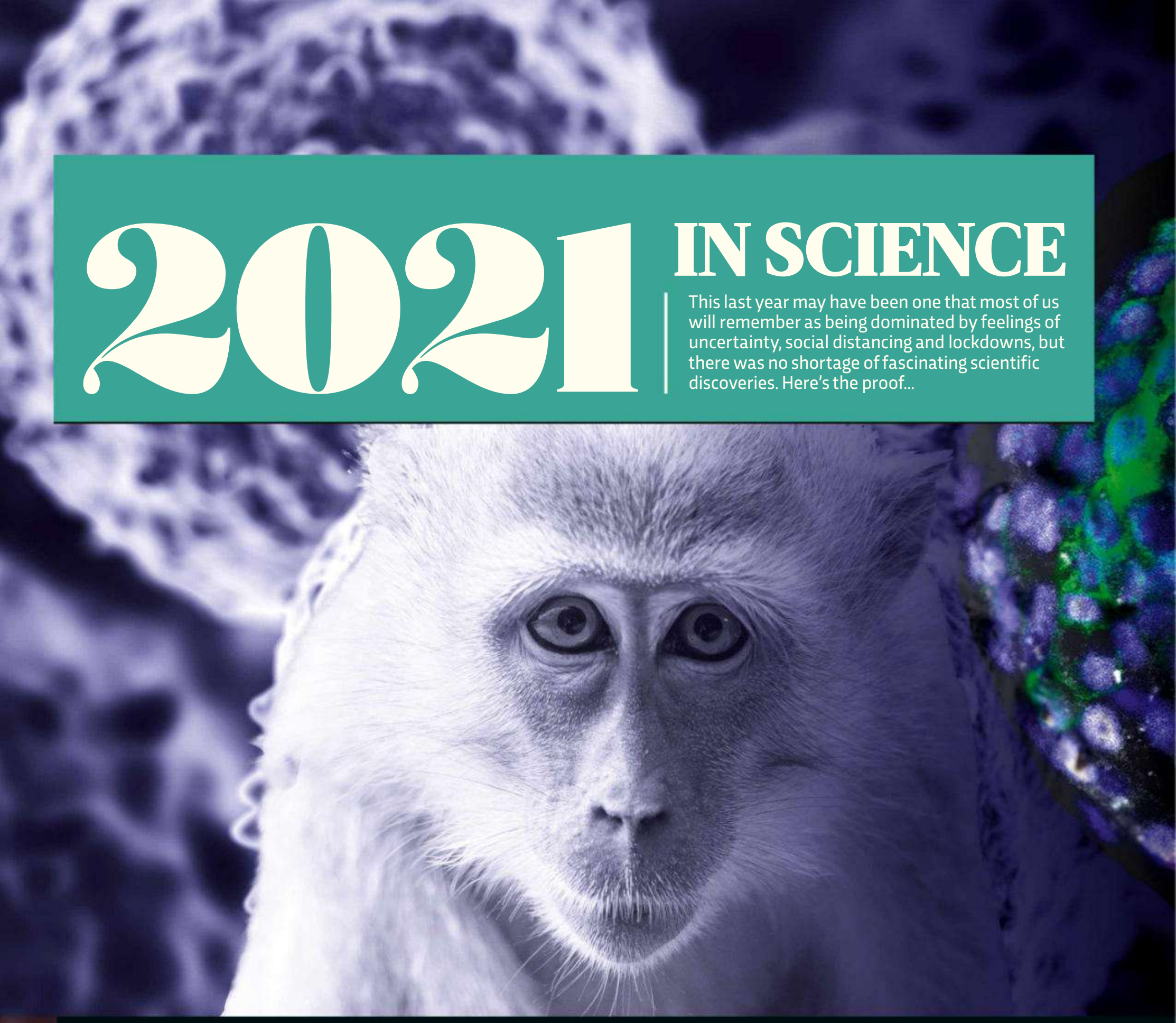
They were recently awarded £3.5m in funding in an investment round led by Hoxton Ventures and including early investors Creator Fund. They plan to use the money to help create future-proof universal vaccines for several major diseases including COVID and malaria.

"I grew up in Brazil and saw first-hand the impact of infectious disease as my aunt lived her whole life with the devastating effects of polio, a vaccine-preventable disease," said co-founder Ariane Gomes. "The COVID pandemic has reminded us that infectious diseases aren't going anywhere, so we urgently need to develop the next generation of vaccines to help protect us all."

BELOW The new algorithm can correctly predict variants, to help create more effective vaccines

2021 IN SCIENCE

This last year may have been one that most of us will remember as being dominated by feelings of uncertainty, social distancing and lockdowns, but there was no shortage of fascinating scientific discoveries. Here's the proof...



HUMAN CELLS IMPLANTED INTO MONKEY EMBRYOS

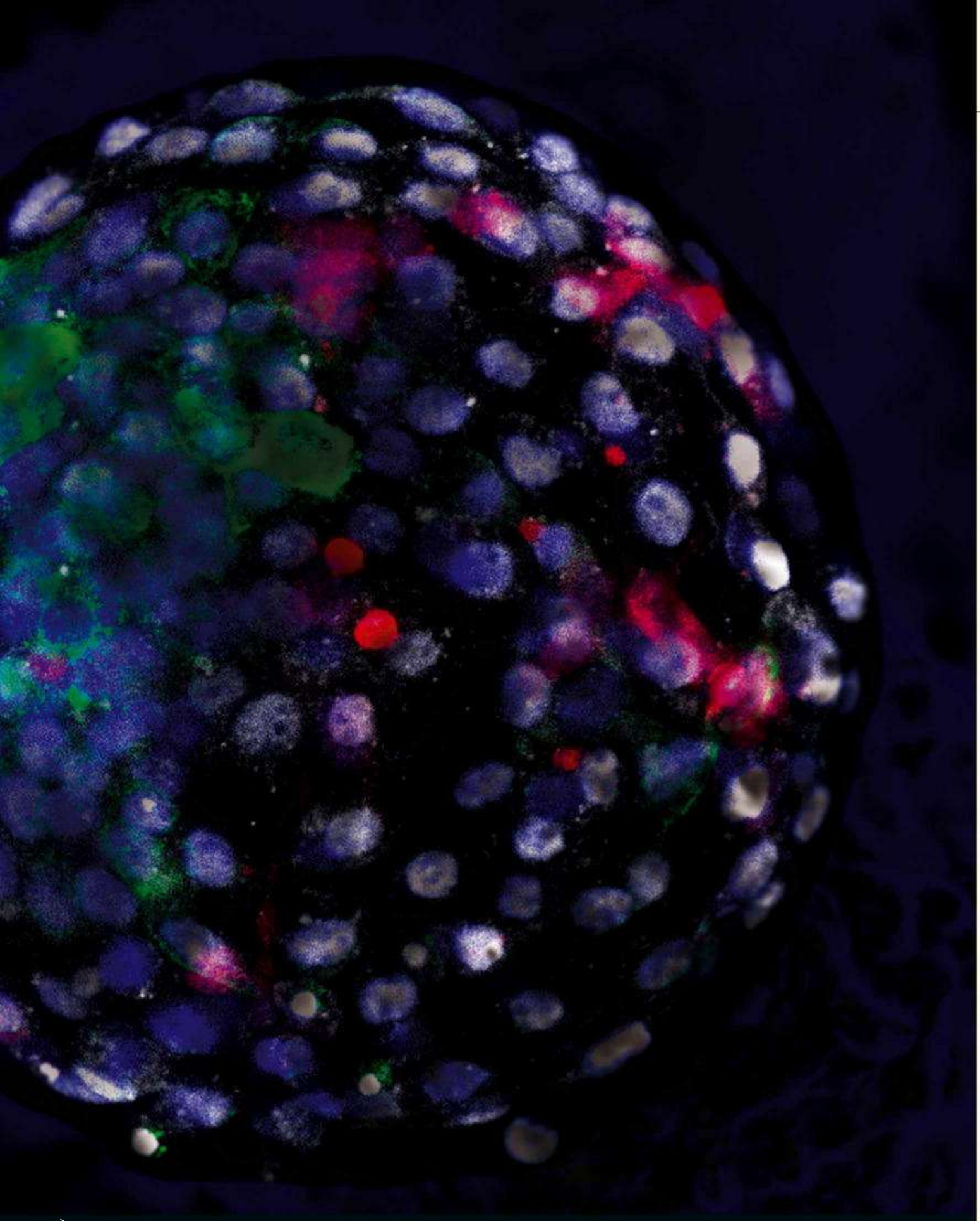
A bold and controversial study, published in the journal *Cell* in April, reported how researchers at the Salk Institute in San Diego had inserted human stem cells into the embryos of monkeys. The embryos survived in the lab, outside of an animal, for up to 20 days – longer than in any similar experiment. The researchers also noticed communication pathways form, which may explain how human cells could better integrate with non-human cells in future experiments.

Work on this kind of hybrid organism, known as a chimera, is conducted for two main reasons. First, it could allow researchers to create 'model' human cells to study disease and new drugs, without breaching the ethical codes that prevent the same work being carried out on actual humans. Second, it could enable the growth of new organs for human transplant.

Researchers have tried the same thing with other animals, such as sheep and pigs, in the past, but the chimeras didn't survive for long. Pairing the human cells with a non-human primate is both the reason it worked better (because we're closer in evolutionary terms) and the reason the work is controversial.

"The closer your model gets to being human, well, the closer your model gets to being human," said Prof Henry Greely, director for the Center of Law and Biosciences at Stanford University. He co-authored a response to the Salk study, laying out some of the ethical questions this kind of work raises.

Human cells were implanted into the embryos of long-tailed macaques (*Macaca fascicularis*)



GETTY IMAGES, DKIST, WEIZHIJI/KUNMING UNIVERSITY OF SCIENCE AND TECHNOLOGY

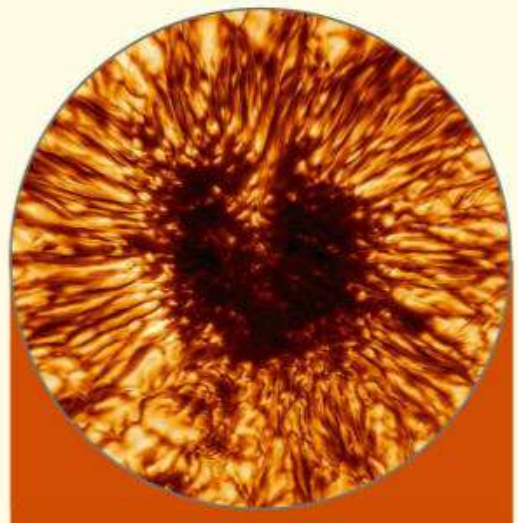
"Xenotransplantation is one of the long-term goals here: to make human organs in another animal and use them for human transplants," he said.

"That's a big deal if you can pull it off. But on a journey of 500 miles, this is a step of one metre. The ethics side is exciting, but depends largely on what happens next."

Greely believes that as long as you're growing the embryos in a dish, it's not a big deal, as far as ethics are concerned. But what if the work advances, and goes from being an embryo in a dish, to one growing in a womb, with a significant number of human cells, which continue to survive?

"That becomes a really interesting question. One is animal welfare: do you let these things be born? What are they? I don't think they're humans, but it's hard to know. Let's say one of them is born and has an enlarged skull and a big brain that looks pretty human. What do we do with that? I think a good starting point for society to come to is [to say]: 'Yeah, we may want to play around with these, but we don't want to implant them.'"

While this kind of biotechnology remains some way off, the field is developing rapidly and Greely says that existing bioethical and legal frameworks are struggling to keep pace. He'd like to see more 'horizon-scanning' groups, whose job it is to look at the direction of travel for a particular kind of research and ensure society is having the required ethical conversations in good time.



SOLAR, SO GOOD

Staring at the Sun is never a good idea, but we'll excuse astronomers using the Daniel K Inouye Solar Telescope in Hawaii. This year they released the most detailed view of a sunspot ever captured. The innovative telescope captures higher resolution solar imagery than ever before and uses a technology called adaptive optics to correct some of the distortions, caused by Earth's atmosphere, that would normally fudge the image. The result: a frightening-but-fascinating look at our star's behaviour, which could eventually help us predict GPS-bothering solar flares. Looks a bit like the Eye of Sauron, no?

PYTHAGO-WHO?

Like 1066 and oxbow lakes, Pythagoras' Theorem was one of the things we all picked up at school. But it seems that Pythagoras wasn't the first person to suss it out. (A quick refresh: the sides of a right-angled triangle follow the equation $a^2 + b^2 = c^2$. So if you add the squared lengths of the sides that form the right angle, you'll get the squared length of the hypotenuse.) August saw Australian mathematician Dr Daniel Mansfield publish his analysis of a 3,700-year-old tablet found in Iraq. It showed that Babylonians were using the same rule to mark and divide up land over 1,000 years before Pythagoras was born.

IS IT HIGH TIME FOR PSYCHEDELIC THERAPIES?

After years of mainstream resistance, the world is, in more ways than one, beginning to change its mind on psychedelic drugs. The therapeutic benefits of magic mushrooms, LSD and other hallucinogens are increasingly supported by hard-to-ignore evidence, as the substances become the subject of a major research focus. In 2021, we may even have reached a tipping point of acceptability, not least because of the stark results from one study at the Centre for Psychedelic Research at Imperial College London.

It found that psilocybin, a substance derived from magic mushrooms, was at least as effective in treating depression as escitalopram. All the patients also received psychological support during the trial. This was a randomised, controlled, double-blind study, and the head-to-head design suggests that psilocybin offers better outcomes for patients than escitalopram, which is one of the most commonly prescribed selective serotonin reuptake inhibitors.

"On almost all measures, psilocybin worked significantly better and faster than escitalopram and was at least as well tolerated," said Prof David Nutt, one of the study's authors. The measures include self-reported symptoms, chance of remission and adverse side effects.

Psilocybin remains a class A drug in the UK and possession is punishable by up to seven years in prison. Elsewhere, however, its legal status is being reassessed. "In the US, many places are removing the illegal status of magic mushrooms in part to accelerate research and treatment," Nutt says. "The UK is lagging behind despite our being leaders in the field."

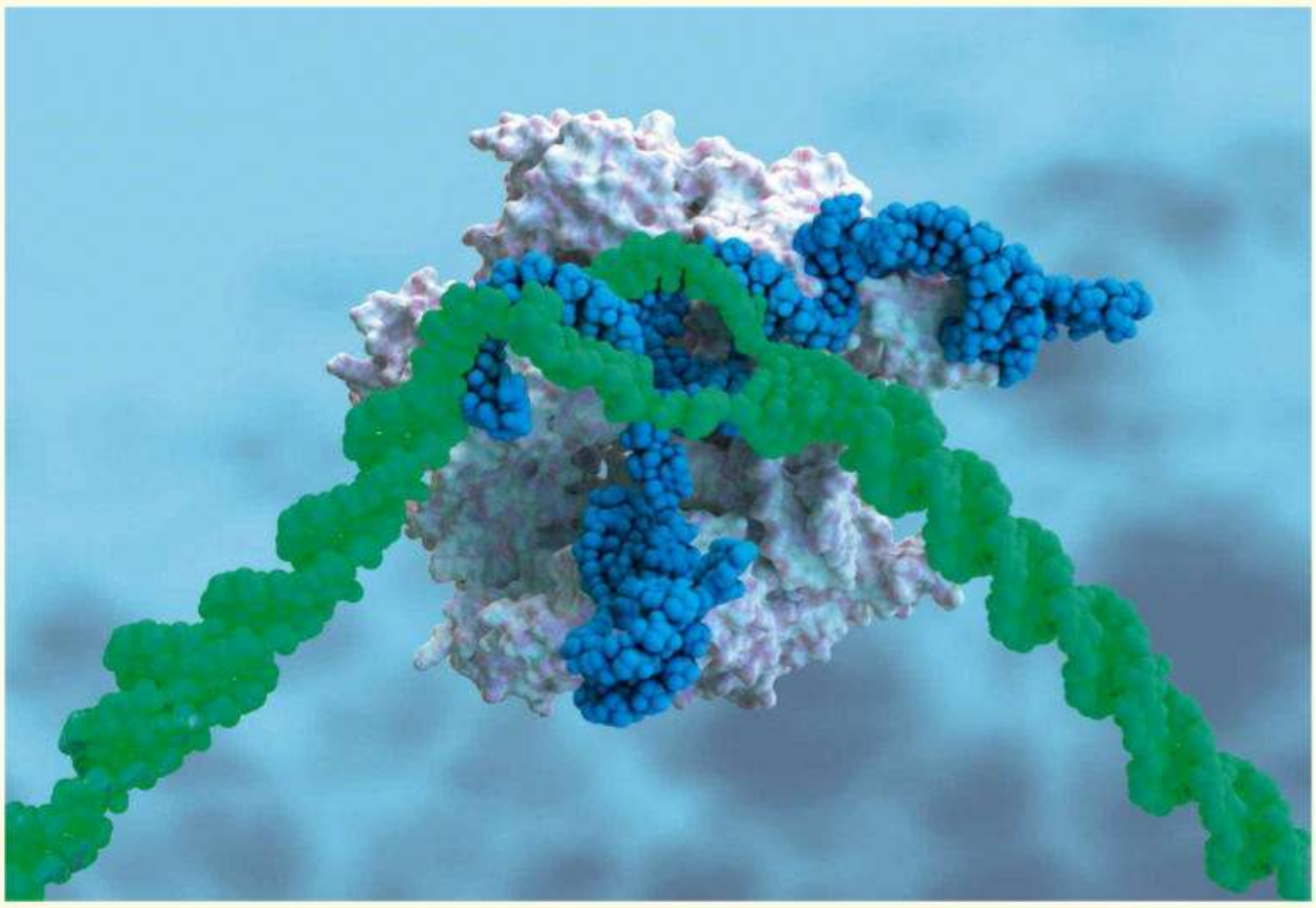
Perhaps spurred on by the success of medical cannabis (economic as well as therapeutic), there's a growing sense of normalisation about the substances and their therapeutic potential. Multiple studies on a wide spectrum of conditions are either planned or underway all over the world.

"We have started our trial of psilocybin in anorexia nervosa and will start one on obsessive compulsive disorder and pain in the new year," Nutt said.

He and his colleagues are also researching other psychedelics, such as LSD and DMT, while another strand of investigation focuses on the therapeutic practicalities of using these drugs.

Earlier this year, researchers at University of California, Davis, reported work on a psychedelic compound that may not have hallucinogenic side effects. This could be important as those kinds of side effects require that patients receive a lot of hands-on psychological support before and after treatment.

Meanwhile, a team at the University of Copenhagen found that psilocybin enhances our emotional response to music – something they say should be considered if the drug is approved for clinical use.



CRISPR CONTINUES TO CRUSH IT

Gene editing is a branch of science developing at paradigm-shifting speeds and this year, the milestones in human health kept coming. In June, researchers announced extraordinary results from an extraordinary new technique, where the CRISPR Cas-9 gene editor was – for the first time – injected directly into the bloodstream of a patient with a rare inherited disease. Normally, CRISPR works by extracting cells from a patient, editing them in a lab and returning them to the body. It's costly, time-consuming and hard on patients who sometimes undergo chemotherapy as part of the process.

The CRISPR technique was relatively quick, and successful too: the treatment saw a huge decline in destructive proteins that build up in the body's organs and tissues in the previously untreatable condition transthyretin amyloidosis.

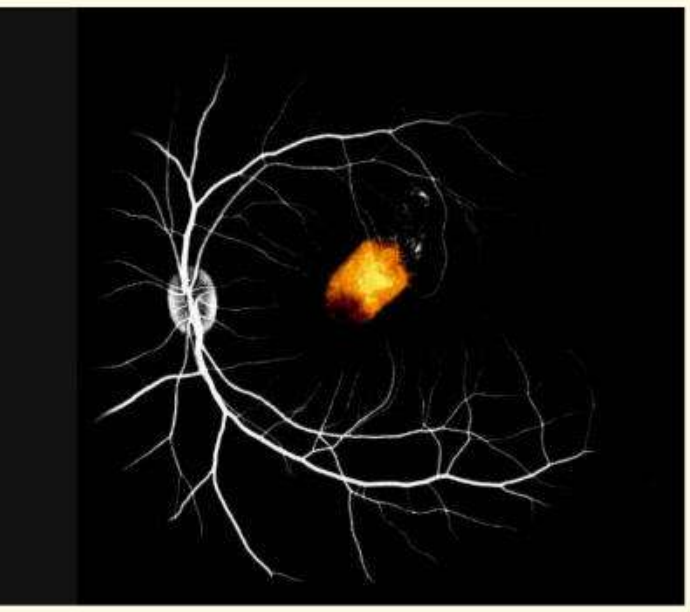
READ MY ROBOTIC LIPS

Watch out Cyberdyne Systems! This year roboticists at Edinburgh Napier University developed a humanoid robot that can lip sync with speech. The robot, which one of the designers modelled on his dad (below), borrows technology first developed for 3D animated characters. Using an algorithm that recognises patterns in speech, the robot interprets that data as jaw and lip movements, accurately mimicking the way a mouth moves to produce speech. Despite the warnings of James Cameron's back catalogue, researchers say this kind of robot will help people interact with technology in new ways.

CATTY BEHAVIOUR

If I fits, I sits. Cat lovers everywhere know how much felines enjoy sitting in a box. The behaviour, observed in big cats as well as domestic moggies, is believed to make them feel safe and concealed – handy, because they evolved as ambush hunters. Now a citizen science project led by researchers at Columbia University in New York has found just how deep-rooted the behaviour is. The project found that cats will even sit in imaginary boxes. Cat owners created square shapes on the floors in their homes, using stickers or tape, and watched as their pets plonked themselves in the middle of them.

GETTY IMAGES, SCIENCE PHOTO LIBRARY, DR CARL STRATHERN, GABRIELLA SMITH/COLUMBIA UNIVERSITY



A BLINDNESS TREATMENT IS IN SIGHT

Hope continues to grow that we will soon be able to treat and reverse blindness, with a number of promising avenues of research showing progress. This year, researchers successfully transplanted human retinal cells into the eyes of monkeys. The researchers that carried out the procedure found no signs of unwanted side effects, such as light sensitivity or dangerous immune responses. Grown from human stem cells donated to science, the cells began to take over control of some functions of the monkeys' eyes. Human trials may not be far away, but researchers at Icahn School of Medicine in New York say that first the technique needs to be tested on monkeys with impaired vision.

The BiVACOR artificial heart relies on a pump that's suspended by magnets

SKIPPING TO THE BEAT OF AN ARTIFICIAL HEART

Researchers have been trying to build an artificial heart for more than 50 years. Now, an Australian team is planning human trials for a design that could have huge implications for our health. BiVACOR is revolutionary because it doesn't attempt to work exactly like a real heart – it tries to one-up evolution instead with an efficient and sustainable way to pump blood around the body. It utilises spinning disc technology, which sees a circular pump suspended between magnets in an artificial heart made of titanium. So far, the technology has only been tested in animals and temporarily in heart transplant patients, although a full human trial is on the horizon. If it works, it could be massive – a quarter of all UK deaths result from heart disease.

SWINECRAFT: EXPERIMENT TURNS PIGS INTO GAMERS

It sounds like total trotters, but pigs are smart enough to play video games. In a study at Purdue University, four pigs moved a joystick with their snouts to direct a cursor to on-screen targets. Researchers noted that their performances were well above those that could be explained by chance, and that the pigs responded to food rewards and verbal encouragement. It's the latest work to hint at the breadth of porcine intelligence, with past research highlighting their learning, memory and problem-solving abilities. Don't you hate it when another player hogs the joystick, though?

PETER ADAMS, AMANDA SMITH/CAMBRIDGE UNIVERSITY, ALAMY, ESTON MARTZ/PENN STATE UNIVERSITY

AS THE RESEARCH BASE GROWS, IT MIGHT NOT BE A CASE OF IF, BUT WHEN WE FIND ET

Somewhere out in the depths of the cosmos, life could be thriving on a strange kind of planet. Around 2.6 times the size of Earth, this alien world would be hot and covered in ocean, with an atmosphere that's rich with hydrogen. Humans couldn't survive there, but maybe we could detect the creatures that do. It's even possible we could make that detection – and confirm that we're not alone in the Universe – in the next two or three years.

This radical idea comes from researchers at the University of Cambridge, who published a paper in August speculating on the existence of such a world. Researchers have dubbed the category a world like this would belong to as Hycean planets. If the existence of Hycean planets is confirmed, it could turbocharge the search for extraterrestrial life because detecting biosignatures from such worlds is potentially a lot easier than doing the same for Earth-like planets. Plus, a lot of already known exoplanets could fall into this class.

"The fundamental advancement here is that this idea will expand and accelerate the search for life elsewhere," said study author Dr Nikku Madhusudhan. "In a very practical sense, it literally increases our chances."

Traditionally, astronomers have scanned the skies for hints of oxygen, methane and other biomarkers produced in large quantities by microorganisms here on Earth.

"On Hycean worlds, we'll be looking for molecules such as methyl chloride and dimethyl sulphide," said Madhusudhan. These are also produced by life, but in much smaller quantities – something that's not a problem when it occurs on Hycean worlds.

"The observability of these [planets'] atmospheres would be so good that even if these molecules are present at one part per million, they'll still be observable," he said.

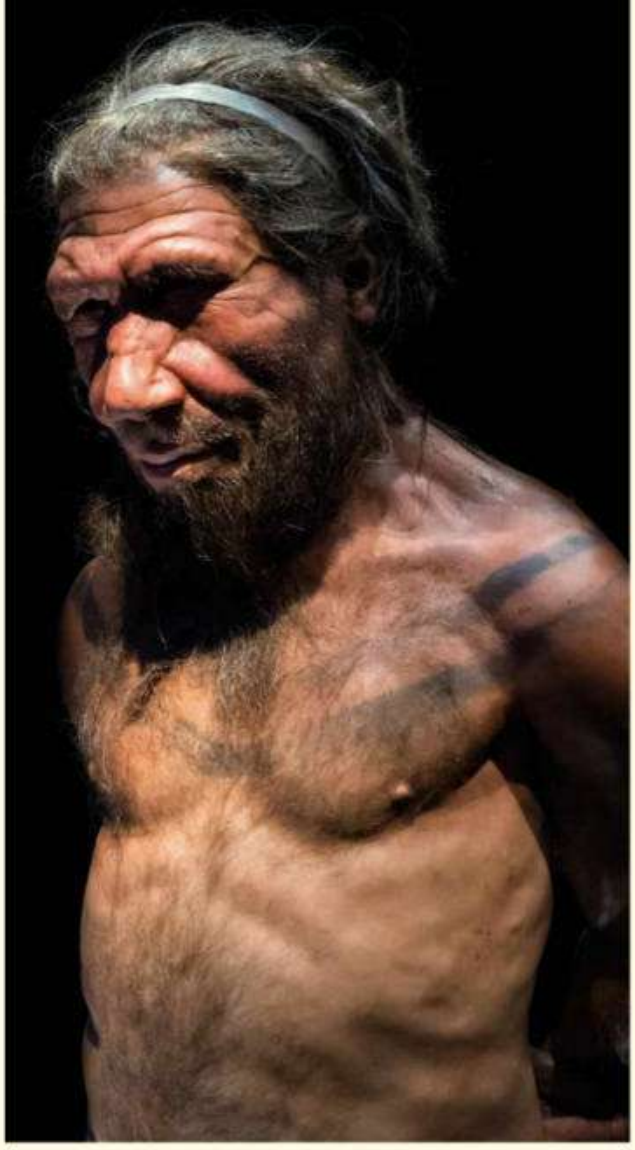
Madhusudhan hopes to take advantage of the soon to be launched James Webb Space Telescope, the largest space telescope ever built. He believes that all it would take is a few hours trained on a Hycean planet for the telescope to pick up biosignatures using transit spectroscopy (a technique in which researchers measure the changes in starlight as it filters through the atmosphere of a planet that's passing in front of it).

As significant as such a discovery would be, it would also beg further questions. "One fundamental question would be: is life possible in such environments? And how would life originate on this planet? You need to do a lot more follow-up observations to robustly establish whether [what you're seeing] is indeed a signature of life," said Madhusudhan.

"I may be risking making a big statement here, but this could be our entry point to extraterrestrial biology. But if you're quoting me on that, please make it clear I'm saying it with some caution!"

NEANDERTHALS: ALL TALK?

Big talk from palaeontologists this year, who claimed that Neanderthals had the capacity to hear – and possibly speak – just like us high-minded *Homo sapiens*. Once dismissed as uncultured knuckle-dragging cave-dwellers, perspective on our evolutionary cousins has been shifting in recent years. They may have worn ornamental dress, for example. We certainly share DNA with them, and now researchers believe there's a good chance they were capable of sophisticated verbal communication. The conclusion comes from researchers in Madrid, who created 3D models of the ear structures of Neanderthals, allowing them to model the frequencies at which they could hear. Neanderthal hearing was attuned to frequencies around 4-5kHz, which happens to match the majority of human speech sounds. Researchers believe if they could hear it, there's a good chance they could speak it.



WHAT HAVE WE FOUND AT MARS THIS YEAR?

2021 has been a busy year for the Red Planet. Three missions arrived in February, having set out seven months before to take advantage of the alignment of Earth and Mars's orbit, an event that only happens once every 26 months.

The first mission to arrive on 9 February was the United Arab Emirates' Hope orbiter, the nation's first planetary mission. The spacecraft's goal is to study the past and present climate of Mars from orbit. Unlike previous missions from other space agencies, which would only look at specific locations at the same time, Hope will look at changes throughout the day. Over time it will monitor Mars's daily, monthly and yearly changes to build up a comprehensive image of what the weather is like on the Red Planet.

The next arrival – Tianwen-1, belonging to the Chinese National Space Agency (CNSA) – reached Mars a day later, on 10 February. The spacecraft spent its first few months at Mars surveying the surface from orbit, reconnoitring for the next stage of the mission: setting down the Zhurong rover. The CNSA eventually selected a site in the large Utopia Planitia and successfully touched down on 22 May. The main goal of the mission was a test of China's ability to operate on the surface of Mars, paving the way for future missions, however, both orbiter and rover are equipped with cameras, radar and spectrometers that will continue to survey the planet's surface and atmosphere.

But, back on 18 February – before the Tianwen-1 mission had located a landing site for the Zhurong rover – the last, and largest, of the three missions arrived at Mars, in the form of NASA's Perseverance lander. It touched down in the Jezero Crater, near what appears to be the site of a past river delta, making it a great place to study the history of water on the Red Planet and its potential past habitability.

Soon after this shot was taken, two drilled sample-collection holes would appear in 'Rochette', the grey rock in front of Perseverance

Perseverance is closely based on the design of its predecessor, Curiosity, but has one major addition – a suite of instruments dedicated to drilling and storing rock samples from the Martian surface. But although Perseverance is a highly equipped robo-geologist, there's only so much you can pack onto a rover and send to Mars. To truly understand the planet (particularly if we want to find evidence of any past life) scientists need to be able to study a Martian sample in the best labs here on Earth. Perseverance represents the first step in that process. It will spend the next few years travelling across Jezero Crater, collecting up to 43 rock samples that it will then leave in caches for a future mission (currently being planned by NASA, in collaboration with the European and Japanese space agencies) to collect and return to Earth.

Perseverance attempted to collect its first sample on 5 August, only to discover the next day that the sample vessel was empty, as the rock appears to have crumbled as Perseverance pulled it out of the ground. The rover moved to a more solid-looking rock, nicknamed Rochette, and successfully stored its first sample on 7 September.

At the time of writing the rover had travelled over 2.6km – quite a fast pace for a Martian rover. Its progress has been aided in large part by a spacecraft that hitched a ride to Mars with Perseverance: the Ingenuity Helicopter. The small drone-like rotocraft is a technology demonstration mission, intended to see if it's possible to fly through the thin Martian atmosphere, the answer to which is a comprehensive 'yes'. Since its first 39-second test flight on 19 April, Ingenuity has flown over a dozen times, travelling more than 2km.

More elaborate missions using the same technology are being planned, but as Ingenuity is only equipped with a camera, it's being used to scout ahead of Perseverance, highlighting any potential hazards or objects of interest.

So what have we learned at Mars this year? The UAE learned how to orbit, China learned how to land, and NASA learned how to fly. SF

Jezero Crater, as seen by ESA's Mars Express orbiter, before NASA's Perseverance began exploring the area

NASA/JPL X2

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REALITY CHECK

SCIENCE BEHIND THE HEADLINES

Super colds | Pedestrian crossings | Tuskless elephants

REVIEW

CORONAVIRUS: IS THE UK IN FOR A WINTER OF 'SUPER COLDS'?

Thousands of people are reporting coming down with bad colds following the relaxing of coronavirus lockdown measures

"While there's no specific super cold that we should be worried about, viruses like the flu continue to change and evolve during the course of the year"

Visit the BBC's Reality Check *website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

WHY DO WE GET A 'COMMON COLD' SEASON AND TYPICALLY WHEN DOES IT OCCUR IN THE UK?

Every winter we have the 'cold and flu' season when cases of respiratory virus infections increase. These winter respiratory viruses include the flu virus, which can cause severe infections, and rhinoviruses, which causes more mild 'colds', though there are many other respiratory viruses that spread in the winter.

In the UK, the cold and flu season is typically between October and March and coincides with the onset of winter weather. It is thought that there are three main reasons for this seasonal increase in respiratory virus infections.

First, many viruses transmitted in the air by aerosols and respiratory droplets survive and spread better in cold, dry weather. Second, our behaviour tends to change in the winter, with people spending more time with others indoors where respiratory viruses transmit better. Finally, for many people, our immune systems do not perform as well in the winter. This is partly due to the lower levels of sunlight causing a reduction in the levels of vitamin D and melatonin, both of which play roles in the functioning of our immune systems.

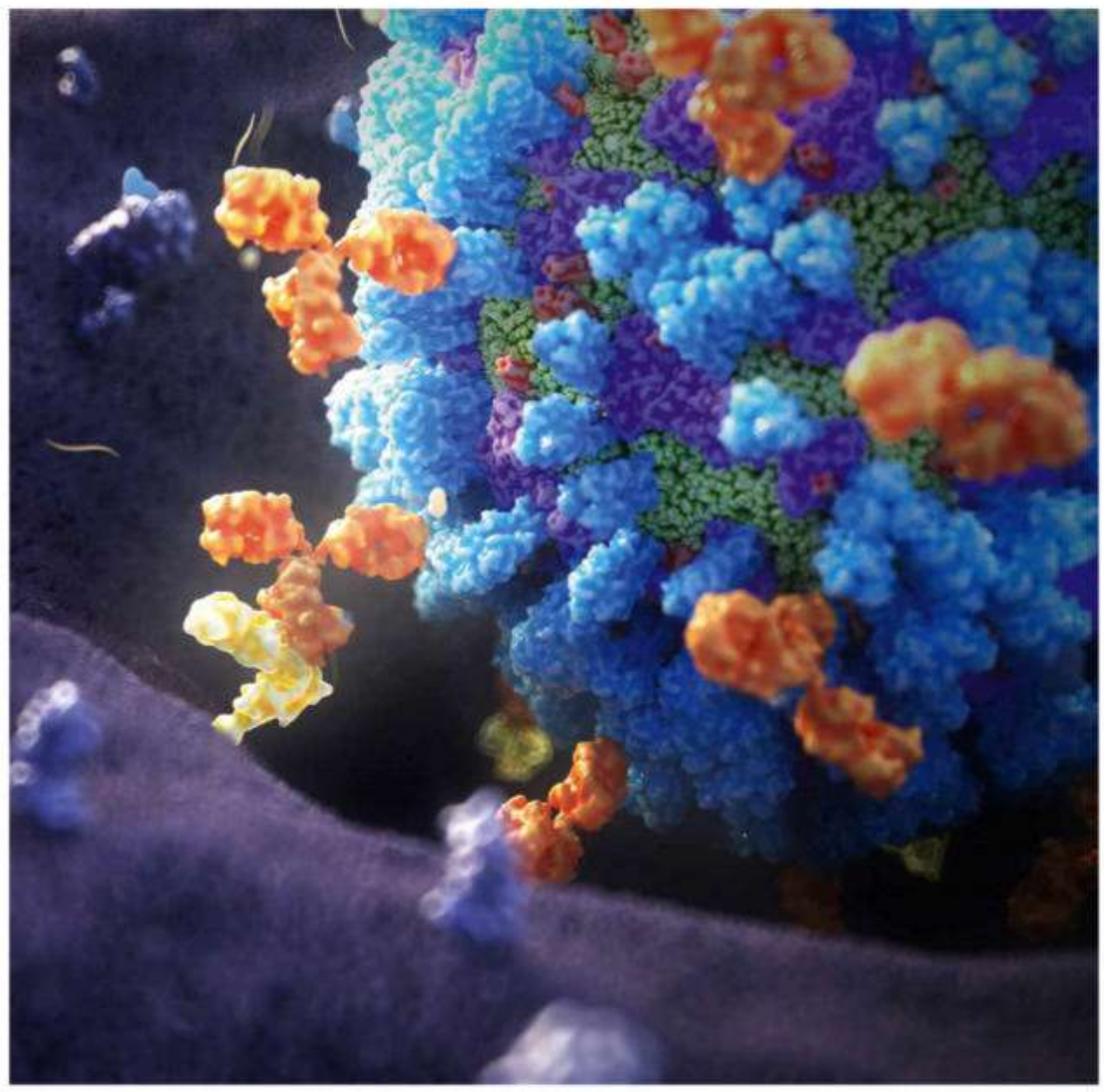
HOW HAVE COVID RESTRICTIONS AFFECTED THE COLD SEASON?

The 2020-2021 winter cold and flu season was unique in seeing some of the lowest rates of respiratory virus infections in recent history. It's thought that this dramatic reduction was due to the COVID-19 precautions that we were taking over the last winter. COVID-19, just like flu and many winter cold viruses, spreads through the air.

Because of this, the measures that are so effective at reducing COVID-19 transmission, such as face masks, indoor ventilation, physical distancing and hand hygiene, will also be effective at reducing the transmission of many other respiratory viruses. The use of these measures is why we had such a mild cold and flu season last year.

WHAT IS A 'SUPER COLD'?

The question many of us are asking is what to expect for the coming winter, given that the use of COVID-19 preventative measures have largely been repealed in the UK. It has been suggested that we might see a 'super' cold and flu season with widespread transmission of these viruses because our collective immunity may have waned over the past year and so more people may be susceptible to infection. In this scenario, the actual infections would not necessarily be any more severe than in a typical winter – although don't forget that a flu infection can still be debilitating, and even dangerous for some members of society.



BELOW Human antibodies (orange) neutralising a flu virus particle (blue)

GETTY IMAGES X2

We are already seeing indications of increased respiratory virus infections in children, specifically the dangerous respiratory syncytial virus, or RSV. Over the past summer we saw high levels of RSV infections in areas where COVID-19 precautions were relaxing. It is very possible the level of RSV and other respiratory viruses will continue to increase over the coming winter in areas without mitigation measures in place.

Another concern is that there will be a 'super' strain of cold or flu viruses that will spread better or cause more severe disease, just as we've seen with some of the COVID-19 variants. While there's no specific super cold that we should be worried about, viruses like the flu continue to change and evolve during the course of the year. Thus, it is possible that the version of the flu virus that we see spreading this winter will be more severe or transmissible than we've seen before; however, there is no reason to assume that will definitely be the case. It is just as possible that this year's flu strain will be milder than we've seen in past years. Of greater concern is co-infection. Studies have shown that co-infections between flu and COVID-19 are possible and can greatly increase virus transmission and disease severity.

WHAT ARE THE BEST WAYS TO PROTECT YOURSELF FROM CATCHING OR SPREADING A COLD?

Regardless of the exact strains of cold and flu viruses that are going around this winter, we know what we need to do to reduce the spread and protect ourselves: wear face masks in indoor spaces, carry out physical distancing, pay attention to hand hygiene, ensure good indoor ventilation and get vaccinated – both for COVID-19 as well as the flu. All of these measures will also help to protect against the spread of COVID-19, which still has high transmission rates in the UK and will likely continue to pose a risk to health and wellbeing throughout the winter.

by **DR JEREMY ROSSMAN**

Jeremy is a senior lecturer in virology and is the president of Research-Aid Networks at the University of Kent. His research focuses on the process of infectious disease outbreaks, and he has contributed to studies published in journals including PLoS Pathogens, Bioinformatics *and* Cell.

ANALYSIS

COLOURFUL CROSSINGS: WILL THEY MAKE OUR STREETS SAFER FOR ALL?

UK councils are upgrading pedestrian crossings to encourage more people to walk safely across the road. But the science isn't black and white...

The streets of London are notoriously colourful, and even more so now that some local authorities have joined the Asphalt Art Initiative and decided to dress up pedestrian crossings in Pride colours or other equally bright designs. Some of these 'colourful crossings' being

GETTY IMAGES

installed by councils around the UK are created with more than just aesthetics in mind, focusing instead on preventing pedestrian casualties. These upgrades have been done in the name of behavioural science.

Two cities in England that have just finished a pilot experiment with the vibrant aesthetics are Liverpool and Hull. The former had 99 adult deaths or serious injuries per 100,000 people in 2019 – making it the worst place in the UK that year – while in Hull, 44 casualties per 100,000 people were recorded.

"We call these colourful crossing 'a nudge' because in an urban environment pedestrians have a choice about where they cross the road," says Dr Holly Hope-Smith, head of behavioural science at So-Mo, the consultancy working on the two trials. "We're trying to enhance a crossing that's already there so that people are more likely to use them."

While Hope-Smith conceded that there had been little in terms of international research into colourful crossings, in 2004, research from Australian academics concluded that coloured surfaces on crossings had a positive effect on pedestrian safety with regards to the number of collisions and the severity of injuries sustained. They recommended that they be implemented in "busy" and "complex" pedestrian environments.

ABOVE This crossing was designed by behavioural interventions agency So-Mo to encourage greater use of crossings at an accident blackspot in Liverpool

"Colour crossings can be really disorientating for people with low vision and their guide dogs"

A year prior to this, an American study found that 41 per cent of survey respondents favoured coloured paving as a pedestrian. Other street designs ranked higher, though, with 83 per cent saying that a midblock crosswalk influenced their decision to cross the road at a specific location, and 74 per cent said that a pedestrian traffic light affected their crossing behaviour.

More recently, a 2017 report by Better Bankside about artworks implemented at crossings in London's Southwark Street said: "[Our] interventions did make respondents more disposed to using the crossing, and 68 per cent told us that the artwork made them feel happier."

Yet bright colours aren't for everyone. Autistic people have raised concerns over the overwhelming nature of having colours on a road, while guide dog owners have reported their dogs being confused by the designs.

"Colour crossings can be really disorientating for people with low vision and their guide dogs," says Dr Amy Kavanagh, a blind activist and campaigner. "I find some of these crossings physically painful and so disorientating I become dizzy. They have caused my guide dog confusion and even distress."

According to a 2018 analysis by Dr Rachel Aldred from the University of Westminster that used data from 2007 to 2015, disabled people are five times more likely to be injured by a motor vehicle compared to non-disabled people. It means that there were 22 injuries reported among disabled pedestrians per million miles walked, as opposed to 4.8 for non-disabled people.

In September of this year, a coalition made up of charities such as the Alzheimer's Society, RNIB and Scope published an open letter to the Mayor of London, Sadiq Khan, raising concerns around the safety and accessibility of the Asphalt Art Initiative, which

These crossings may look eye-catching, but they can be tricky for people with disabilities to navigate

is part of Khan's Let's Do London campaign to encourage domestic tourism to the city.

"The project demonstrates exactly what happens when meaningful engagement does not take place: it sadly results in schemes that are neither accessible nor inclusive," the letter reads, citing issues with people with learning disabilities struggling to interpret artwork as crossings.

Khan later responded to confirm that he has asked Transport for London (TfL) to "introduce a temporary pause" on colourful crossings. The decision was made "in light of the growing concern" about their impact on disabled people, and new TfL research. Khan added that new guidance on colourful crossings would be developed over the next year in consultation with organisations representing disabled people.

The conflicting needs of different people has sparked another conversation about the most inclusive solution. How can bright and colourful crossings be created in a way which cuts pedestrian casualties, without creating a whole new issue which puts disabled people at risk?

"These crossings are placed to enhance existing smart pedestrian crossings," Hope-Smith says. "All the cues that are there for impaired road users remain – the touch sensors, the audio cue for when the crossing is on – we haven't touched them."

In the case of the Liverpool and Hull pilot, the trial ran until the end of October 2021 and the data is now being transferred to an independent company for analysis. The findings, Hope-Smith says, should be done by the end of the year.

—

by **LIAM O'DELL**

Liam is an award-winning deaf journalist and campaigner. He writes regularly for The Independent *and the popular deaf news website,* The Limping Chicken.

COMMENT

ELEPHANTS: WHY ARE THESE ICONIC AFRICAN ANIMALS LOSING THEIR TUSKS?

A genetic analysis suggests that African elephants are evolving to be tuskless, and it seems that poaching could be to blame

List an elephant's most iconic characteristics and tusks should be right behind the long trunk, and arguably ahead of big ears and thick skin.

Tusks are elongated teeth that grow continuously and are used to dig for food and nutrients, clear paths through vegetation, mark or remove tree bark, and for fighting between males. The tusk can serve those diverse purposes thanks to the properties of its main material, ivory, which makes it strong and tough.

Ivory's impressive properties make it attractive to humans. Traditionally used to make art and ornaments of cultural value, ivory has become a valuable status symbol. But as studies have shown, demand for ivory has helped to fuel a multibillion-dollar wildlife trade that encourages illegal hunting. And now new research has found that this may also have left an evolutionary mark on elephants.

A study by biologists at Princeton University looked at African savannah elephants in Mozambique's Gorongosa National Park. During a civil war that lasted from 1977 to 1992, more than 90 per cent of large herbivores were slaughtered, including elephants. The elephant population dropped from more than 2,500 individuals 50 years ago, to less than 250 in 2000.

And while the population decreased, the proportion of female elephants without tusks increased: comparing historical videos to modern footage showed a rise from 19 per cent to 51 per cent. Among females born after the war, one-third are tuskless.

In mammals, sex is dictated by a pair of chromosomes: females are XX, males XY. Because nearly all male elephants have tusks, the Princeton biologists suspected that the tuskless mutation was linked to the X chromosome. After searching the genomes of 11 tuskless elephants for signatures of recent evolution, the biologists found one relevant DNA sequence on the X chromosome: AMELX, a gene that helps produce enamel and cementum, two minerals that coat tusks and teeth.

GETTY IMAGES X2

"As tusklessness existed before the war, the trait probably isn't caused by new mutations, but by rare genetic variants that are now more common in the gene pool"

A pattern of inheritance predicts that all daughters of two-tusked mothers should be born with two tusks or none at all, but 1 in 10 female elephants have one tusk or zero, so the trait must also be influenced by a second genetic factor. By comparing DNA from tusked and tuskless elephants, the researchers identified another gene, MEP1a, which is involved in producing dentin, the core mineral in ivory.

As tusklessness existed before the war, the trait probably isn't caused by new mutations, but by rare variants that are now more common in the gene pool. Driven by the harvest of elephants for ivory, the tuskless trait has become more common as females born without tusks are likelier to survive and reproduce.

Though humans are technically part of nature, calling that process 'natural selection' is vague. The evolution of tuskless elephants is an example of 'harvesting selection' or 'human-driven selection'.

Despite tusks being useful, the fact that females can cope without them suggests they aren't essential for survival. Indeed, of the three living species of elephants, females of the forest and savannah elephants tend to be tusked, but female Asian elephants might only have short protrusions called 'tushes'. Tusks don't seem to be vital to Asian males either: in Sri Lanka just 10 per cent are tusked.

One explanation is that 3,000 years of hunting and domestication favoured the loss of tusks in Asia, whereas African elephants have only recently been exposed to human-driven selection.

So yes, elephants are losing their tusks. But while it's tempting to focus on how we are altering another animal's anatomy, it's difficult to untangle the feature from the dramatic drop in population size: according to figures from the World Wide Fund For Nature, African elephants numbered three to five million in the early 20th Century; today there are just 415,000.

The issue extends beyond elephants. The world's largest living land animal will bulldoze its way through habitats, which can trigger a transition from forest to grassland and change the local composition of species. Elephants are 'ecosystem engineers' whose behaviour has knock-on effects. Compared to the human-driven selection that's driving the loss of tusks, which has taken mere decades, the ecological functions played by elephants can't be restored quickly. As the Princeton biologists conclude: "Restoration of these functions may require disproportionately longer time scales than the initial selection event." **SF**

ABOVE African elephant herd with a tuskless matriarch

by **DR JV CHAMARY**

JV is a science communicator with a PhD in molecular evolution and genetics.

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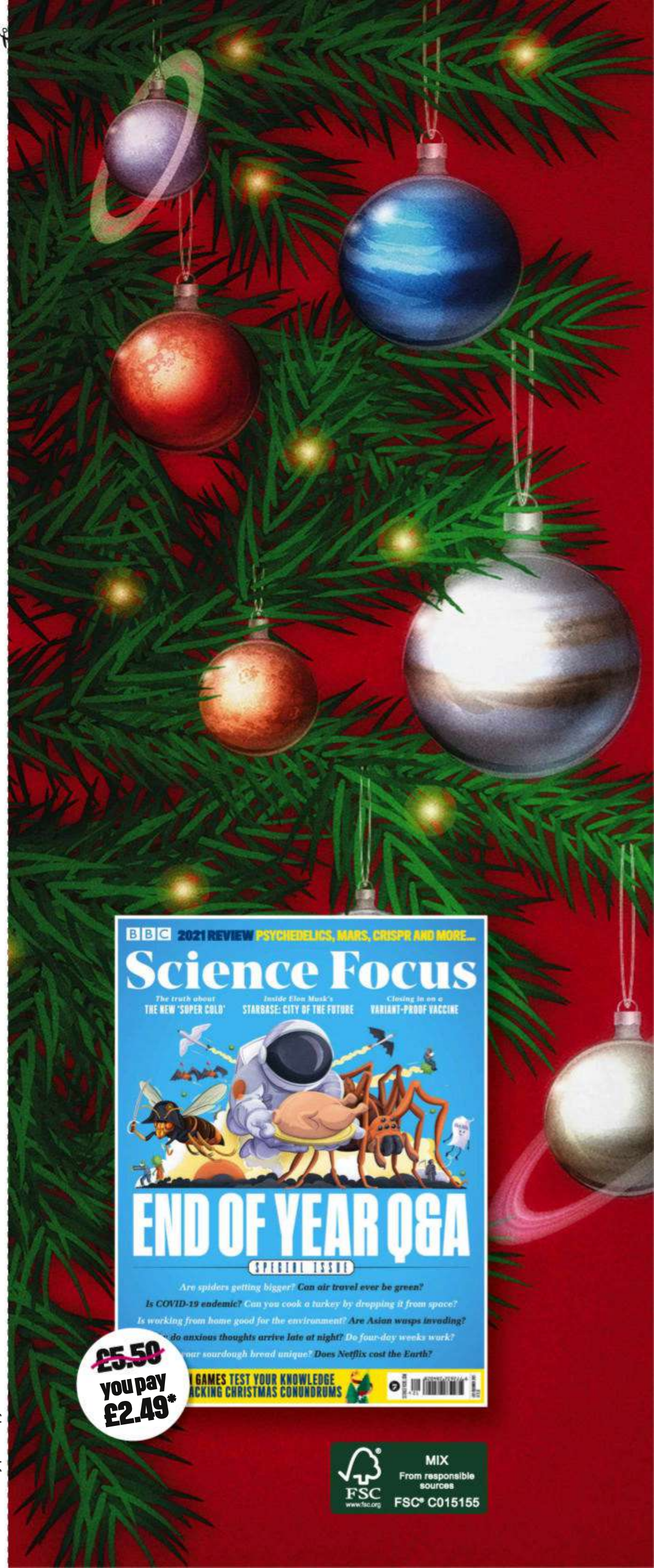
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CHRISTMAS WISHLIST

Last year, Christmas getting cancelled taught us that family really is the most important thing at this time of year… Pah! Christmas is about presents, pyjamas, pigs in blankets, Die Hard*, preposterous sandwiches made of leftovers and migraine-inducing volumes of fizz. In that spirit, here's our pick of the best presents that money can buy...*

...the podcast lover

The third generation of Apple's wireless earbuds now come with spatial audio (a kind of surround sound), a battery that lasts longer and charges faster, and a new, improved skin sensor that pauses your audio when you take them out of your ears. Spatial audio takes these earphones to a level above and beyond other earphones out there, squeezing impressive cinematic sound out of teeny, tiny speakers.

APPLE AIRPODS
£169, APPLE.COM

...those who can't be bothered to clean their oven

If the Instant Pot (an electric pressure cooker, slow cooker hybrid) was last year's must-have kitchen gadget, this year it's all about air fryers, which blast food with ultra-hot air to make it taste as though it's been deep-fried. You can thank TikTok for their popularity, where home cooks use them to make viral recipes like pasta chips, giant cookies and full English breakfasts. Our pick would be this dual zone cooker that can dehydrate foods to make snacks like jerky, and has a 'Match Cook' mode, which makes sure that the food in both compartments is hot and ready at the same time.

NINJA FOODI DUAL ZONE AIR FRYER AF300UK
£179.97, NINJACOOKING.CO.UK

...the frugal gamer

Pound for pound, an Xbox Series S paired with an Xbox Game Pass is the best value for money in gaming right now. The Xbox Game Pass, at £10.99 a month, gives you access to a huge library of games, including classics such as *Alien Isolation*, indie hits including *Unpacking,* and the latest blockbusters like the upcoming *Halo* release.

The console itself doesn't have the power to pump out 4K graphics like its bigger brother the Series X, but unless you have a 50-inch TV, you'll hardly notice the difference.

XBOX SERIES S WITH GAME PASS £249 AND £10.99 A MONTH XBOX.COM

...fashionable teenagers

This black-on-black design from Casio is effortlessly cool. It's much slimmer and smaller than the traditionally chunky family of G-shock watches it comes from, but it's just as tough. The watch is water-resistant to 200m, and is also shock-proof and cold-proof. Perfect if you fancy a bit of Christmas snorkelling…

An instant classic.

CASIO OCTAGON SERIES £99, CASIO.COM

...the Apple disciple

If you've got an Apple obsessive in your life, this might be the perfect gift. The stand will wirelessly charge an iPhone, AirPods and an Apple Watch all at once and hold them in place with Apple's MagSafe tech.

BELKIN BOOSTCHARGE PRO 3-IN-1 WIRELESS CHARGER £139.95, BELKIN.COM

...the one in your life with terrible sinuses

This is an air purifier, humidifier and fan all in one. Sensors inside will detect air pollution – more often than not fumes from cooking and cleaning – and fire up the fan to filter the particles out of the air. It's a godsend in a small flat or apartment where it's tricky to get good air circulation. In the winter months, the humidifier conditions the air, which can help those of us with sinus issues that get agitated by winter heating.

DYSON PURIFIER HUMIDIFY+COOL £599.99, DYSON.CO.UK

...the one who's always in the wrong clothing

This jacket is built to shield you from whatever weather the winter months will throw at you. Really, it's built for those people who like to schlep up mountains, but it's a perennial favourite of ours since it uses smart materials to provide its waterproofing rather than any kind of coating, which can run off and dissolve over time. This means that in theory the coat will remain waterproof but breathable for its entire life without any need for reproofing.

ODIN 9 WORLDS INFINITY SHELL JACKET £430, HELLYHANSEN.COM

...those who use fairy lights all year round

This adorable lantern doubles as a Bluetooth speaker. The speaker and light at the base of the device work together to emulate a flame dancing to the rhythm of your music. A knob at the side allows you to adjust the warmth and intensity of the light, from candlelight to reading light. It's reasonably weatherproof too, so it can sit outside – though we wouldn't leave it out in the rain.

TRANSPARENT LIGHT SPEAKER FROM £290, TRANSPA.RENT

...the PC gamer

Mechanical keyboards, with spring-loaded keys that click as you type, are gaining a cult-like following right now. In theory, the physical feedback of a click with each keypress makes for fewer errors, plus their design means that the keyboard is more repairable and customisable. YouTube is overflowing with videos showing you how to build your own, but this Logitech is a hassle-free option. It's got Bluetooth switches for connecting devices and 'lightspeed' wireless for optimal gaming.

LOGITECH G915 TKL
FROM £199, LOGITECHG.COM

...the budding hi-fi nerd

Grado is a family-run business that makes headphones and earphones out of Brooklyn. These headphones generate a dynamic, warm sound with tonnes of detail, comparable to kit carrying a much bigger price tag. The open-backed design is intended for home-listening sessions, meaning that they generate a big, roomy sound, but they also leak too much noise to take them on the train.

GRADO SR80X
£129.95, GRADOLABS.COM

...night owls

The AeroPress is such a popular way to make coffee that it has its own championships where brewers compete to make the best cup of joe – presumably there's also a long line for the loos. Now there's a travel edition of this popular coffee maker for the caffeine addict in your life. The whole kit packs into a package smaller than a can of pop and will make some of the best coffee you can find without having to endure someone in a flannel shirt explaining why you shouldn't really add milk to your brew.

AEROPRESS GO,
£31.99, AEROPRESS.CO.UK

...the person in your life who's about to start commuting again

This gaming controller essentially transforms your smartphone (iPhone or Android) into a Nintendo Switch. Although you won't be able to enjoy Mario's latest adventures, you can pair this hardware with a cloud gaming service like Google Stadia or Xbox Game Pass to enjoy blockbuster games like *FIFA 22*, *Cyberpunk 2077* or *Far Cry 6* on your phone. What better way to avoid everyone at Christmas?

RAZER KISHI
£89.99,
RAZER.COM

...the home worker who has developed a hunch

No one wants to look up your nostrils during a video call, which is why anyone working from home deserves a laptop stand: it will elevate their webcam and bring their display closer to eye level. With its flat base, this sleek-looking model from Twelve South takes up almost no precious desk space, and its design means the height and angle of your laptop are easily adjusted to suit your setup. It's built for MacBooks, but it will work with other laptops of a similar size and scale.

TWELVE SOUTH HIRISE ADJUSTABLE STAND FOR MACBOOK
£59.99, TWELVESOUTH.COM

...those of us who still love Lego

Want to shut the family up after Christmas dinner? This 62cm-tall AT-AT from Lego should do the trick. As ever, it's the little details that make our inner child squeal with joy. The walker's sides open up to reveal several bays where you can house your stormtroopers, and inside the head there's an adorable pilot's bay from which you can rain death upon rebel scum. There's even a tiny rappel gun that Luke can ascend the AT-AT with. It's pricey though, so if you actually want to pay your rent there's a smaller, simpler one available for £139.99.

LEGO AT-AT
£749.99, LEGO.COM

...the person whose phone is always out of charge

This smart little battery pack magnetically snaps on to the back of your phone and recharges your phone wirelessly to give your smartphone an extra day or so of battery life. Although most new smartphones available in the last year offer wireless magnetic charging, check the compatible models before buying.

MOPHIE SNAP+ JUICE PACK MINI
£38.85, ZAGG.COM

...those of us who've had quite enough of the real world this year

Although Mark Zuckerberg's vision for a future – where we all work from home and don headsets when we want to collaborate in a virtual space – sounds like our idea of personal hell, it hasn't dampened our love of virtual reality. Since the Oculus Quest's release, a gentle trickle of experimental experiences and games have made it to the platform. The thrill of the new is ever-present in VR games, compared to traditional consoles which, let's face it, after the 72nd *Call Of Duty* game can feel a little stale. Plus, with a little messing about in the settings you can stream what's going on inside the headset to a nearby TV, which makes for a great evening of party games with friends.

OCULUS QUEST 2
FROM £299, OCULUS.COM

...small people with sticky hands

For all our talk of console gaming and virtual realities, what the kids (and the *BBC Science Focus* team) really want is the latest Nintendo Switch. The screen is sharper and brighter with better contrast, and most importantly larger. The docking system, which connects it to your TV, has had an upgrade too. There's no extra graphical power here, but that doesn't matter for those of us dying to get our hands on the new *Metroid* game, or the upcoming *Pokémon* and *Zelda* sequels.

NINTENDO SWITCH OLED
£309.99, NINTENDO.COM

...the nostalgic

For many of us, the commute is making its return to our daily lives. If your trip's short enough, why not ditch the car and make your daily travels a thing of joy, with an electric bike? Our personal pick would be a Super 73, which harks back to classic Honda scooter designs from the 1970s and 1980s. The entry-level model, the ZX, offers a respectable range of 40-48km (25-30 miles) and a top speed of 25km/h (15mph). It comes with chunky tyres that can travel cross-country, should you feel the need to do some sick jumps and skids.

SUPER73-ZX
€2,499 (APPROX £2,110)
EU.SUPER73.COM

HERE COME

CHRISTMAS WAS CANCELLED LAST YEAR FOR MANY OF US. JUST IN CASE THIS YEAR SUFFERS THE SAME FATE, WE'VE ROUNDED UP A SELECTION OF WINTER SOLSTICE CELEBRATIONS FROM AROUND THE GLOBE. AFTER ALL, YOU CAN'T ABOLISH AN ASTRONOMICAL EVENT!

WORDS: HAYLEY BENNETT

S THE SUN

GETTY IMAGES

A NEW DAWN

WILLKAKUTI CELEBRATION, BOLIVIA

Roman pagans celebrated the shortest, darkest day, or winter solstice, on 25 December, welcoming the longer daylight hours ahead. This is probably why we celebrate Christmas on this date; not because it was Jesus' birthday. As astronomy presenter Colin Stuart explains: "Before temples made way for telescopes, many civilisations saw the Sun as a god. On the winter solstice… they figured that the deity was furthest from the Earth and so did all they could to beckon it back again to warm and sustain them for the year ahead." We now know the astronomical reason for the solstice: the Earth is tilted on its axis. On 21 December, in the northern hemisphere, the Earth receives the least light it will get all year because it is most tilted away from the Sun, while the southern hemisphere has its winter solstice in June. Bolivians celebrate Willkakuti ('return of the Sun') on the 21 June, coinciding with New Year for the Amayran people of the Andes. The ruins at Tiwanaku are a popular place to greet the dawn, as the Sun appears through the entrance of a pre-Incan temple.

←

SOARING INTO THE SEASON

LOHRI FESTIVAL, INDIA

In Hinduism, the Sun god Surya is a chariot-riding deity. Surya also refers to the Sun and the early astronomy text the *Sûrya Siddhânta,* which describes the motions of the planets and the Moon. However, Indian solstice celebrations relate more to astrology than to astronomy, with the bonfire festival known as Lohri falling on 13 January, when the Sun is about to transit from the constellation of Sagittarius into Capricorn. The following day is Makar Sankranti, which marks the start of spring. Besides being a chance to usher in a new season, these festivals now provide an outlet for India's love of kite-flying. In 2020, locked-down Indians bought kites in their millions to fly from their roofs and terraces; by Lohri 2021 some kite sellers were complaining of running out of stock.

GETTY IMAGES X2, SHUTTERSTOCK

BRING OUT YOUR DEAD!

INTI RAYMI FESTIVAL, PERU

Countries that sit nearer to the equator, like Peru, experience a softer sort of solstice – the days never get that short or dark. But this doesn't dim the Peruvians' celebrations. Held on 24 June, Inti Raymi is named after Inti, the Incan Sun god. Stuart refers to it as his favourite solstice celebration. Why? "They get their mummified ancestors out of their tombs for the day and loft them through the streets," he says. It's true – or, at least, it was for the Incas, who would gather at the plaza in the Incan capital Cusco, having collected their dead. They would then continue this party with ritual sacrifices to Inti, involving hundreds of llamas. Today, the festival's colourful dresses and dances entertain a crowd of thousands in what's touted as a re-enactment of the ancient gore-fest, albeit minus the mummies and with just one (mock) llama sacrifice.

ORIGIN STORY

ENTRUDO CARNIVAL, PORTUGAL

The Romans celebrated Saturnalia, dedicated to the god Saturn, between 17 and 23 December. It was a sort of late harvest festival associated with feasting and fertility. Confusingly, this is considered to be one of several holidays that may have given birth to Shrove Tuesday, when in the UK people feast on pancakes before the Lent fast. It is also thought to have influenced the tradition of Entrudo, meaning 'entry' (into Lent), which began in Portugal in the 13th Century. Though Entrudo takes various forms in different regions, it has often involved chauvinistic rituals, as well as general misbehaviour such as throwing buckets of water and flour. In the village of Lagoa, the men dress in white shirts and red skirts with striped aprons and wear masks known as campina (pictured). Despite its questionable origins, Entrudo is currently having a revival.

KINDNESS

ALAMY

PASSAGE OF TIME

BURNING THE CLOCKS FESTIVAL, UK

A modern solstice festival, Burning the Clocks in Brighton, UK, isn't exactly steeped in ancient tradition – it only started in 1994 – but visually it does have a touch of the pagan about it. Every year, local community groups pour their energies into creating hundreds of paper lanterns, clocks and representations of mystical figures so that they can march them down the main street before ritually burning them in one giant bonfire on the beach. The parade is organised by the arts charity Same Sky, whose artistic director is John Varah. He says the solstice was chosen because it has significance in many traditions but is "owned by none". As for the clocks, they symbolise the enemy or the governor. "So at the end of the solar year, we burn these symbols," says Varah. The parade was cancelled in 2020 due to COVID-19 restrictions, but local shops and public spaces hosted a lantern trail instead.

↓

IN A SPIN

SANTO TOMÁS FESTIVAL, GUATEMALA

Due to its vicinity to the equator, Guatemala's winter solstice, like Peru's, is much less extreme than what we experience closer to the poles. Even in mid-winter, there are still 11 hours of sunlight, which just equates to more time for partying, particularly in the otherwise quiet town of Chichicastenango. In December, 'Chichi' bursts into life, celebrating for a full week ahead of 21 December, with dancing, colourful costumes and pole-flying, an apparently ancient tradition passed down from the town's Mayan ancestors. The pole-flyers or 'palo voladores' are masked marimba dancers dressed as monkeys or jaguars, who climb a death-defyingly tall pole and then spin from it by ropes attached to the top. Other dances include an adapted Mayan fertility ritual and a dance to honour the town's Christian patron saint, Saint Tomás. While this all seems somewhat far-removed from the solstice, its roots are in the customs of the Maya people who worshipped the Sun as a god and were fascinated with its movements. A few hours north, Mayan ruins hidden in the jungle at Ceibal include some of the oldest known solar observatories.

EUROFUSION CONSORTIUM, ELLE STARKMAN/PRINCETON PLASMA PHYSICS LABORATORY

LIGHT THE WAY

ST LUCIA'S DAY, SWEDEN

It's no wonder the returning light is cause for celebration in Sweden, where in the depths of December the Sun can rise and set between breakfast and lunch. Here, the transition towards longer days is marked by parades of gowned children bearing candles. They are led by St Lucia, 'the bearer of light'. In the Italian tradition, St Lucia was a Christian martyr who wore candles on her head to light her way around the catacombs of Rome, where she delivered food to persecuted Christians, but in Sweden, she seems to have been adopted to embody the pagan Sun goddess Sunna. Megan McQuilton, who moved from the UK to Åsele in Swedish Lapland in 2018, says St Lucia is a "massive" deal for the locals. "It's a cultural tradition they keep up like Christmas and definitely a celebration that we will be going into lighter times," McQuilton explains. The candlelit procession and feast day take place on 13 December, when the Italian Lucia was supposedly killed by Roman guards. The Swedes celebrate by eating sweet, saffron buns called lussekatter and drinking mulled wine (glögg). SF

by HAYLEY BENNETT
Hayley is a science writer based in Bristol, UK.

GETTY IMAGES X2

Photography and videography can change us.
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They change the rules.

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Changing the way others see the world.
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Change the bigger picture.
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Give more people a voice.
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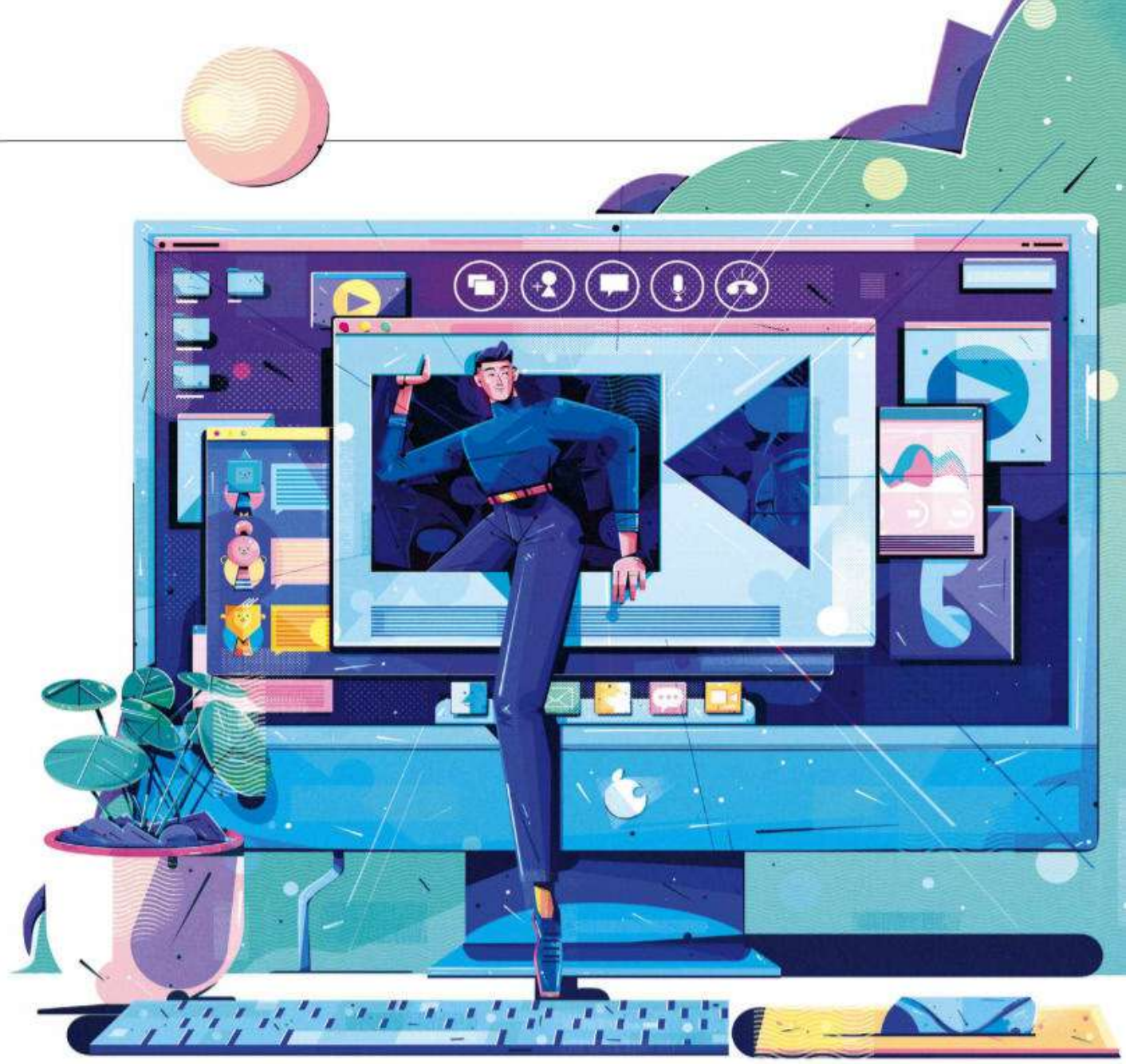

COMMENT

HOW TO TACKLE ZOOM FATIGUE

After nearly two years of working from home, the novelty of video conferencing has rather worn off...

As the New Year approaches, one resolution I am determined to make and stick to is to spend less time on Zoom and other forms of video-conferencing software. What started out as a great way to keep in contact with other people during lockdown has turned into a brain-draining, bottom-numbing experience that has sapped a lot of joy out of my life.

So what is it about spending way too many hours doing video calls that is so soul destroying? For enlightenment, I turned to Prof Jeremy Bailenson, founding director of the Stanford Virtual Human Interaction Lab (VHIL). Earlier this year, he published a study that outlined the theoretical arguments for the causes of Zoom fatigue and why we experience it. He also offered some solutions.

First, when you are on a Zoom call you do an awful lot of close-up eye contact, much more than you would in normal life. In 'real' meetings I spend a lot of time doodling or staring out of the window.

When I was first asked to present a TV series, I went to Jeremy Clarkson for advice (I had just made a series with him called *Inventions That Changed The World*). He told me that the key to being a good presenter is not to stare continuously at the camera, but to spend a lot of time gazing off into the distance, as though thinking. Staring is tiring and makes you look like a psychopath. On top of that we rely a lot on nonverbal communication, and if you are on Zoom you feel obliged to exaggerate those smiles and nods, which is very tiring. One solution is to agree with others that you will turn your camera off when you are not speaking, but continue to listen in. Also, this is a good excuse to leave the room and hope nobody notices...

"One solution is to agree with others that you will turn your camera off when you are not speaking"

Second, seeing yourself while on a conference call is distracting and tiring. As Bailenson points out, we don't normally spend meetings surrounded by giant mirrors. Studies have shown that when you can see yourself you become much more self-critical. I did a small TV experiment where we put muffins and apples on a table in a pedestrianised square with a sign inviting people to help themselves. They overwhelmingly went for the muffins. But when we put a mirror on the table, so they could see themselves reaching for the muffin, many paused and went instead for the apple. You will be pleased to learn that on most video-conferencing platforms there is the option to 'hide self-view'.

Third, video conferencing reduces your mobility. We know that sitting continuously is bad for our health, and that's why, when I am on the phone, I like to walk around. I also find it helps keep me more alert. This is not really an option on Zoom, and though Bailenson suggests you set up your camera so you can pace around, I'm not sure how well that would work in practice. Of course, with your camera off you can fidget and pace to your heart's content! SF

MICHAEL MOSLEY

Michael is a writer and broadcaster, who presents *Trust Me, I'm A Doctor*. His latest book is *COVID-19: Everything You Need To Know About Coronavirus And The Race For The Vaccine* (£6.99, Short Books).

BBC TWO

PORTRAIT: KATE COPELAND ILLUSTRATION: JOE WALDRON

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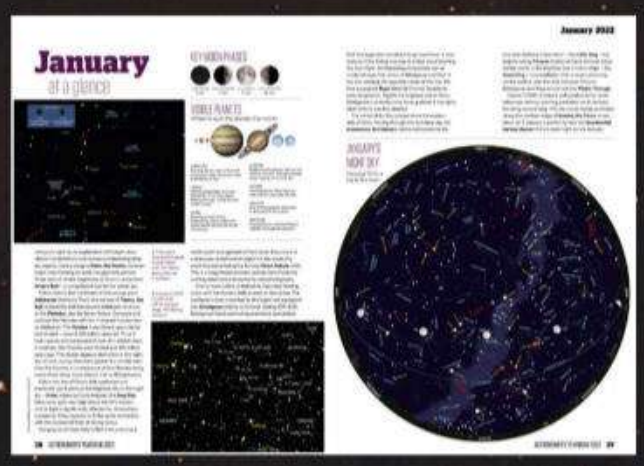

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TERRY HANCOCK

COMMENT

A DANGEROUS RELATIONSHIP?

Any of us can build a following online, but a large band of followers can make it tricky to navigate the turbulent waters of the digital world

When I was nine years old, I was desperately in love with a man who was at least 40 years my senior. Don't worry; it was entirely unrequited – in fact, Mickey Dolenz of The Monkees didn't even know I existed because he'd stopped being a Monkee 20 years earlier. But that didn't stop me from decorating my books with love hearts and 'AK + GMD' (little known fact, Mickey Dolenz's real name is George Michael Dolenz), and entering a pre-teen trance every time I put *Pleasant Valley Sunday* on my record player.

The Monkees were entirely manufactured, I know this now. But as a product they were a success: they used the media to instil a bond between an audience member and her target. In their TV show, they regularly broke the fourth wall, throwing knowing winks to camera. In magazine interviews, they shared intimate details of their hilarious behind-the-scenes lives. They made themselves vulnerable. They made us think we knew them, as a friend.

Recently, when making an episode of *Digital Human* for BBC Radio 4, I discovered that this kind of 'parasocial relationship' has long roots in media. Radio characters like Lonesome Gal fashioned them by cooing into listeners' ears for 15 minutes of monologue once a week from the late-1940s to the mid-1950s. She started most episodes with, "Sweetie, no matter what anybody says, I love you better than anybody in the whole world," speaking directly to her listeners. Each individual felt he (predominantly a he) had her undivided attention. She was an entirely virtual girlfriend, at a time when the word had nothing to do with technology. And eventually, like anyone who cultivates those kinds of relationships, she began to sell things.

"What was once an intimate relationship turns into a business transaction"

Parasocial relationships have become a means to an end in the digital age, now that selling yourself has become a way of life. Manipulating these relationships is how you gain followers, credibility and influence. But maintaining them is a challenge. At the beginning, it's necessary to put out the tendrils of connection as widely as possible. But once you start to gain a critical mass, the relationship necessarily transforms – at least in the eye of the digital personality. You can speak directly to one fan, or even five. But it's not possible to respond to the 10,000 people who subscribe to your TikTok. What was once an intimate relationship turns into a business transaction.

Reaching out across the internet is how we feel connected; imagining we know the person behind the screen is our global folly. Rising social media stars have to manage themselves and their boundaries. That's one of the most untapped skills in the digital age. Today's parasocial relationships are surfing uncharted territory, so it is expected that they – we – will make mistakes.

A person scorned in the era of Lonesome Gal or Mickey Dolenz had intermediaries to intercept; who is there to help when we've put ourselves out there online? SF

PORTRAIT: KATE COPELAND ILLUSTRATION: SCOTT BALMER

ALEKS KROTOSKI

Aleks is a social psychologist, broadcaster and journalist. She presents *The Digital Human*.

BBC RADIO 4 92–95 FM & 198 LW

THE QUESTIONS THAT WE'VE BEEN PONDERING IN 2021

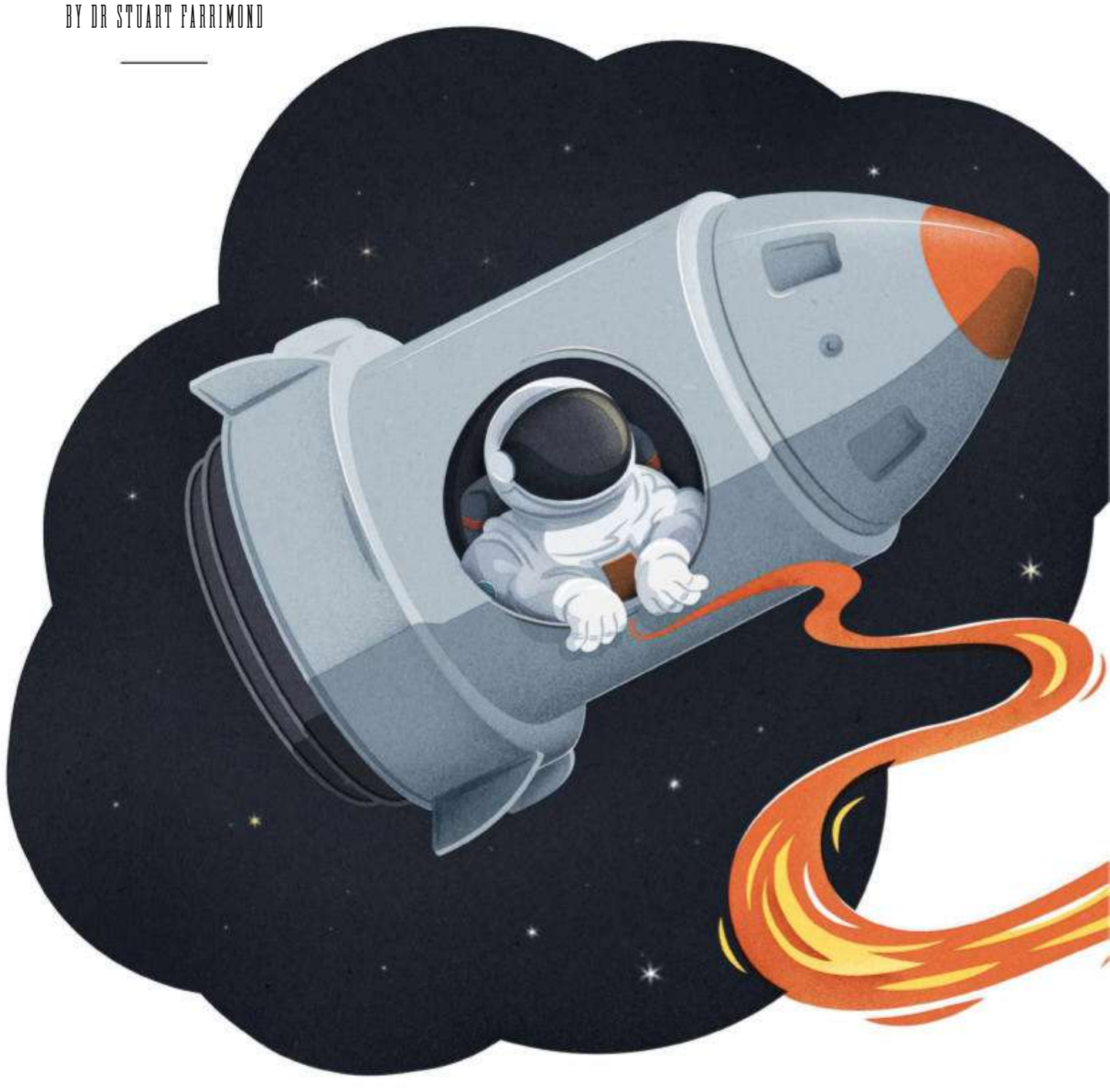
Q&A OF THE YEAR

ANSWERED BY EXPERTS AND THE *BBC SCIENCE FOCUS* TEAM

COULD YOU COOK A TURKEY BY DROPPING IT FROM SPACE?

OVEN DECIDED TO BREAK ON CHRISTMAS EVE? DESPERATE TIMES CALL FOR DESPERATE MEASURES

BY DR STUART FARRIMOND



Some 10 million turkeys are eaten every Christmas in the UK alone, yet it is a meat that many of us love to hate. After all, the line between tender succulence and a mouthful of dried sawdust can be wafer thin. Oven roasting, spatchcocking, spit roasting, deep fat frying... each cooking method has its pros and cons. But part of the issue with cooking the perfect turkey is down to the birds themselves.

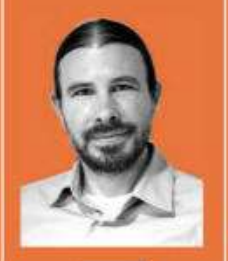
Since the 1930s, turkeys have ballooned – more than doubling in weight as farmers have bred only the biggest, leanest birds. And because they can be so large and low in fat, the outer meat can be overdone and leathery by the time the middle is cooked. As soon as meat reaches around 65°C, it starts to cook: the proteins unravel and coagulate, or 'denature', making the flesh firm and digestible. Supermarket turkeys are considered safe to eat when the deepest part of the meat has reached 70°C. At higher temperatures, the meat gets stiffer and drier. Oven roasting is particularly dehydrating because the cooking chamber is so arid and because heat moves so desperately slowly from air into solids. Try hovering your hand in an oven at 150°C (which is the air temperature) and it will feel hot but not unbearable; yet a mere splash of 100°C water or oil would make your skin blister and burn.

A 180°C oven will take more than three hours to cook a 5kg turkey, whereas deep fat frying – immersing the turkey in the same temperature oil – will do the job in just 35 minutes. Spatchcocking (splitting the turkey down the middle and spreading it flat) lets heat pass into

DR CHRISTIAN JARRETT
Neuroscience expert

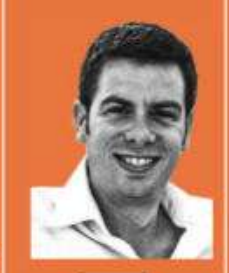
DR JULIA SHAW
Criminal psychology expert

DR PETER BENTLEY
Computer scientist and AI expert



DR JEREMY ROSSMAN
Virologist and infectious disease expert

ALEX FRANKLIN-CHEUNG
Sustainability expert



DR ADAM HART
Entomology and ecology expert

DR STUART FARRIMOND
Food science and health expert

JOCELYN TIMPERLEY
Climate and environment expert

DR ELIZABETH PEARSON
Space expert

the deepest parts more quickly and more evenly, while spit-roasting cooks by direct heat radiating from a flame.

But in this brave new age of space adventure, perhaps it's time to try something completely different. How about cooking it under the power of gravity by dropping it from space? We've all seen images of space shuttles and landing capsules re-entering the Earth's atmosphere in a ball of flame – and that's just like a good barbecue, right?

Given that anything freefalling through the Earth's atmosphere at speed gets very hot – a fiery 1,500°C for spaceships and meteorites alike – you perhaps wouldn't expect to have much edible meat to serve with your Brussels sprouts, but you'd be mistaken. Let's suppose you were to toss a whole fresh refrigerated 5kg turkey out of the hatch of a Jeff Bezos private space flight from a height of 107km, at the edge of space.

At first our intrepid bird will get a brief freeze – at this height, it's a bracing -80°C. Hurtling towards Earth, this high-speed fowl may be setting a world distance record for a flightless bird but its travel time will be surprisingly brief. The first 50 kilometres will pass in a mere 100 seconds, at which point the bird will be diving at three times the speed of sound. Only in the last 30 or so kilometres will the air be thick enough to slow it down and cause heating. At supersonic speeds, air will ram so hard into the spinning turkey that it will be compressed and heated. As soon as the meat's surface temperature climbs to 130°C it will start to brown, causing the building blocks of proteins, the amino acids, to react with traces of sugar in the weird and wonderful Maillard reaction, imparting it with the aromatic meaty yumminess we associate with the festive roast.

Given the intense heating, likely approaching 500°C, the browning reaction will be largely leapfrogged into pyrolysis, or burning, in which molecules are literally ripped apart in the heat, turning charcoal black. Nevertheless, this torching will be mercifully brief as the bird will rip through the last leg of the journey in less than 30 seconds.

So what does that leave for the table? Because heat conducts so slowly through meat, most of the breast meat will be disappointingly rare. Only a very thin rim of meat underneath the blackened exterior would be 'edible'. Of course, the force of impact will be huge, blasting and splatting the centrepiece of your festive feast to smithereens while gifting you with a pretty little crater. Gravy with that, anyone?

ALAMY ILLUSTRATIONS: DANIEL BRIGHT

DID ZOMBIE MOVIES PREPARE US FOR THE PANDEMIC?

BY ALICE LIPSCOMBE-SOUTHWELL, MANAGING EDITOR

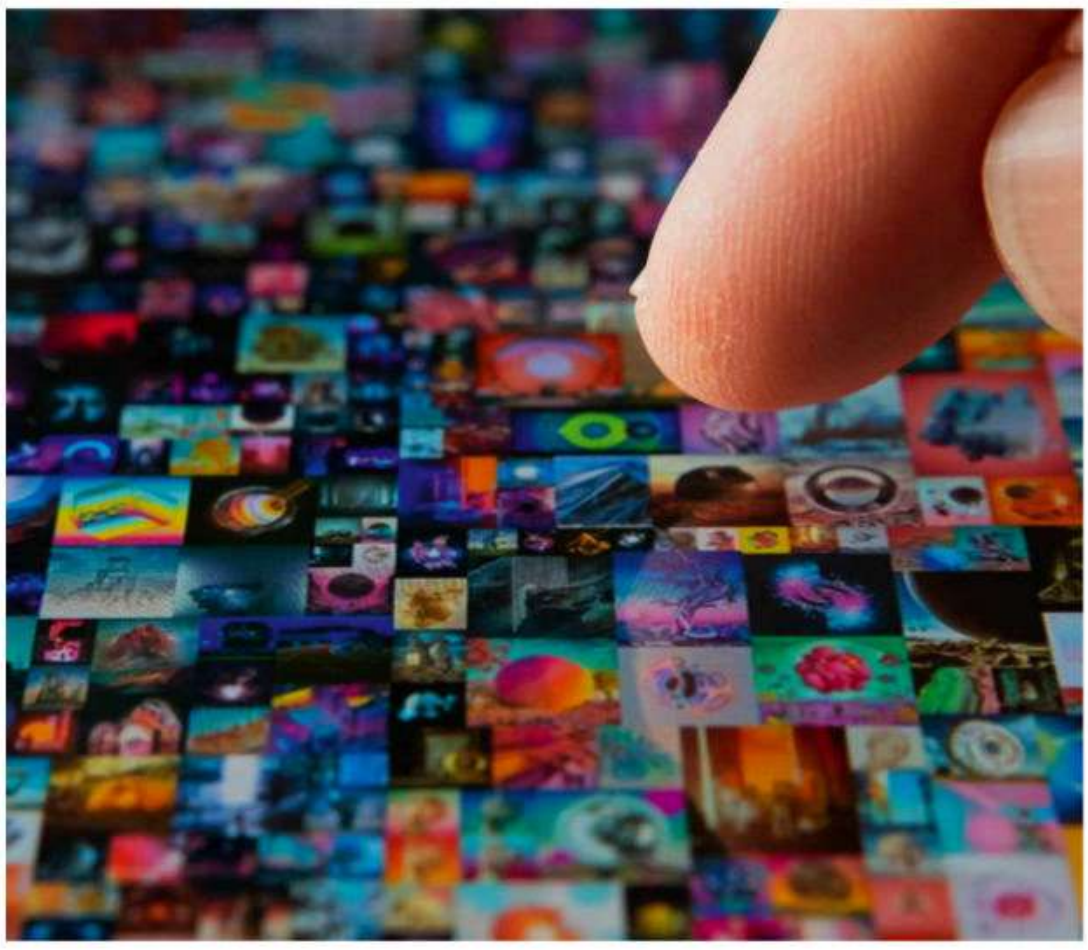
Many of us enjoy post-apocalyptic horror movies, perhaps viewing them as a late-night guilty pleasure. However, research carried out at Penn State University at the beginning of 2021 suggested that people who regularly enjoy these films were better prepared for the reality of the COVID-19 pandemic than those who avoid scary movies. Even after factoring out personality influences, the team still found that the more horror, zombie, alien and apocalyptic films people had watched, the better they coped with the pandemic. The researchers think that these stories act as a mental rehearsal for real life. Pass us the popcorn.

ARE ANIMALS MONOGAMOUS?

BY ALICE LIPSCOMBE-SOUTHWELL, MANAGING EDITOR

Biologists tend to split monogamy into social monogamy (a pair living together to mate, share resources and care for young) and genetic monogamy (a couple exclusively having sex and reproducing with each other). While we may prize monogamy in many human cultures, it's pretty unusual among mammals, with just 3 to 5 per cent of species being socially monogamous. These include a few bats, grey wolves, some primates, prairie voles and Eurasian beavers, among others. In birds, monogamy is far more common with some 90 per cent of species exhibiting social monogamy. It is rare in fish, reptiles and amphibians. Crucially, the definition of 'social monogamy' does not mean that the two animals in a pairing will be faithful to each other. In fact, many will have flings on the side when no one is watching.

It is thought that monogamy evolved to maximise the chances of offspring survival, with two parents available to help with care, feeding and protection.



WHAT ARE NFTS?

BY DR PETER BENTLEY

NFT stands for 'non-fungible token'. The non-fungible part means unique and non-replaceable. No swapping like for like. The token part means it's digital and protected using blockchain technology, like cryptocurrency. NFTs make a lot of sense when used for selling digital art – a digital image can be sold as an NFT, much as you would sell a physical painting, allowing you to own the 'original' version, and the artist continues to benefit every time the NFT is resold. But the idea of NFTs feels questionable when anyone can also have a copy. Nevertheless, NFTs may have a future. They've been used for digital marketing, where an NFT was auctioned for a whisky company alongside an expensive cask of scotch, and in gaming, where you can win digital assets in the form of NFTs that you can later cash in for other benefits. Perhaps one day we may use NFTs as digital certificates for deeds, allowing ownership of houses or land to be traded as a new kind of cryptocurrency.

IS COVID ENDEMIC?

THE EXTENT TO WHICH WE WILL HAVE TO LIVE WITH THE VIRUS DEPENDS ON OUR ACTIONS

BY DR JEREMY ROSSMAN

A pandemic is a new outbreak of an infectious disease that affects a significant number of people in most countries around the world. There are several different possibilities for what happens afterwards. If we could stop all COVID-19 infections around the world then the virus would be eradicated. Unfortunately, eradication is incredibly difficult, and historically we have only successfully eradicated two diseases, smallpox and the cattle disease, rinderpest. If, however, all COVID-19 infections were stopped at a local level (a country or even a community) then the disease would be eliminated. The virus would still be present globally, but there would no longer be any cases within the region. If eradication or elimination are not achieved, but cases are dramatically reduced, then the virus could become sporadic, with occasional infections occurring at low levels.

But what happens if virus transmission continues as it currently is in the UK (with 40,947 new cases as of 27 October 2021)? At some indeterminate point the pandemic would no longer be a new outbreak but would instead become an endemic, where there are regular high rates of the disease that may even be comparable in number to the rates seen during the pandemic phase. While there is no defined point in time whereby a pandemic becomes an endemic, it tends to occur when case numbers stabilise over an extended period of time. One example of a virus that caused a pandemic and now is responsible for a global endemic is HIV, the virus that causes AIDS. Thus, the term we use for describing the current state of COVID-19 infections in a country is guided by the number of cases, the duration the disease has been circulating and the stability of case numbers over time.

The level of cases we see in the UK will be driven by our public health choices. As we have seen from countries like New Zealand, eliminating COVID-19 transmission is possible and would allow the removal of most mitigation measures; however, the risk of resurgence of the virus from other countries requires continual surveillance and public health readiness. In contrast, other countries have removed most or all of their mitigation measures with the aim of living with the virus. This continued virus circulation risks overburdening health systems (perhaps necessitating new mitigation measures) while causing significant health impacts to those infected. There are also additional long-term impacts, as it's estimated that nearly 14 per cent of COVID-19 infections result in symptoms lasting three months or longer.

In between these two extremes are low-level endemicity or sporadic infections. Some viruses that we regularly hear about fall into this category (for example, the measles virus causes sporadic infections in the UK). With COVID-19 at a low endemic or sporadic level, and with high vaccination rates, mitigation measures would not be needed for most of the population. Instead, public health teams would need to investigate and contain any outbreaks at a local level, just as is done with measles.

We have made significant progress in reducing COVID-19 hospitalisations and fatalities; however, case numbers are still high in the UK and in many areas around the world. In addition, many people in the UK remain at risk of COVID-19 disease due to being unvaccinated, being ineligible to be vaccinated (too young to receive the vaccine), or being clinical vulnerable. Because of this, there are significant risks of allowing for high-level endemic COVID-19 disease.

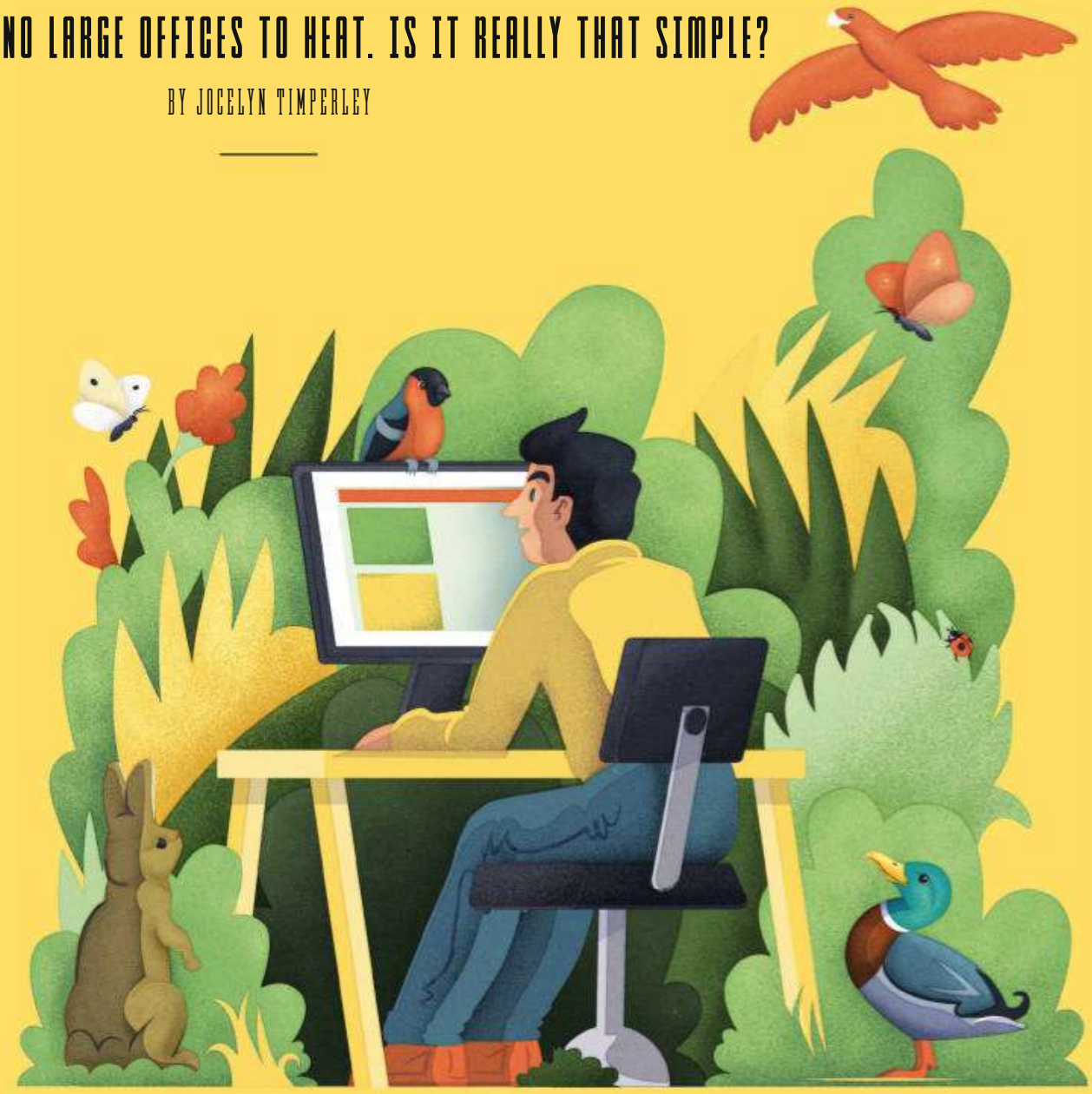
Our actions over the coming months can help drive down new infections while increasing vaccine coverage, potentially enabling the elimination or COVID-19 or the transition to a sporadic or low-level endemic disease, reducing the long-term burden on the NHS. This would protect health and wellbeing while minimising long-term need for population-level mitigation measures.

ALAMY, GETTY IMAGES ILLUSTRATIONS: DANIEL BRIGHT

WILL WORKING FROM HOME HELP THE ENVIRONMENT?

NO COMMUTING, NO LARGE OFFICES TO HEAT. IS IT REALLY THAT SIMPLE?

BY JOCELYN TIMPERLEY



The COVID-19 pandemic saw a huge rise in people working from home. A survey carried out by UK Parliament in April 2020 found 47 per cent of people with jobs in the UK had done at least some work from home that month. Contrast that with a survey the year before where only 30 per cent of workers said they had ever worked from home.

Many now think the numbers of people at the office will never go back to their pre-pandemic levels. In a recent YouGov survey, 70 per cent of people polled said they expected workers to never return to offices at the same rate. And 60 per cent said they would prefer to work remotely at least some of the time if they could choose.

It seems like a no-brainer that these changes would be good for the environment, and several studies have come to this conclusion. Working from home can reduce both travel emissions from people's commutes and save the need to heat, cool, or light offices. Even the European Commission is in on this trick: it announced plans in May 2021 to close half of its 50 office buildings across Brussels, in part to become "more green".

In an analysis last year, the International Energy Agency (IEA) found that for people who commute to work by car more than six kilometres (3.7 miles) one way, teleworking will lead to a reduction of emissions – despite the extra energy consumption due to them staying at home. The analysis also estimated that around a fifth of all jobs globally could be carried out entirely at home. If all these workers worked from home three days a week, it found, around 80 million tonnes of carbon dioxide emissions could be reduced per year – an amount comparable to the entire annual CO_2 emissions of Chile.

Working from home is one of the core "behavioural changes" needed to help achieve net zero emissions in 2050, explains Ariane Millot, an energy analyst at the IEA and co-author of the analysis.

"Teleworking can help to accelerate the reduction of CO_2 emissions that is needed to achieve a pathway compatible with a 1.5°C temperature increase," she says. "The impacts on air pollution are likely to be large and positive."

But when an even wider scope is used to assess the changes in emissions when working from home, the picture is not always so clear, says Dr Andrew Hook, a lecturer in human geography at the University of Sussex and lead author of a 2020 review of 39 studies on the climate impacts of teleworking.

"We find that the more rigorous studies ... estimate smaller energy savings, with a few studies even suggesting teleworking could actually increase overall energy use," says Hook.

The reason for this is that these studies take into account the other changes in energy use that come from people working from home. For example, people working from home most of the time may choose to live further away from their office, making their commute longer on the days they do head into the workplace. They may also end up travelling more for leisure than they would if working in an office, or end up using much more energy when they are at home. Moreover, if offices are kept open, they may still be using similar amounts of energy, even if they are mainly empty.

A report published in June 2021 by the UK's Carbon Trust concluded, for example, that urban German workers who commute by train during the winter tend to have far lower carbon emissions working in the office than at home, due to the energy needed to heat individual homes. However, homeworking did on average save carbon emissions in all six European countries analysed, when looked at over the whole year.

Higher levels of teleworking certainly can lead to reduced energy use and emissions, as well as improved quality of life, says Hook. But to maximise climate gains, steps are needed to minimise these other increases in energy use. This could mean, for instance, better town planning to ensure cafes and shops are accessible by walking, cycling and public transport. Similarly, improving energy efficiency in homes will mean they take less energy and emissions to heat.

Ultimately, the share of homeworking possible will depend on the specific country, its economy and other factors like digital readiness, says Millot. If governments support teleworking in the right way, though, it appears it could make a small but substantial impact on emissions.

ARE SPIDERS GETTING BIGGER?

AS SPIDERS CAME INDOORS THIS AUTUMN, SOCIAL MEDIA WAS CONVINCED THE UK'S ARACHNIDS HAD GROWN IN SIZE

BY DR ADAM HART

John Keats might have described autumn as the "Season of mists and mellow fruitfulness" but for many arachnophobes it's also the season of spiders. As evenings draw in, large spiders scuttling across the floor become a common sight. They are a reliable source of the 'nature scare' stories so beloved of the UK media, but are these spiders really getting bigger, as some reports claim?

The big spiders we often see in our homes are commonly called 'house spiders' but scientifically they belong to two genera, *Tegenaria* and *Eratigena*. There are several different species that are broadly similar and, when fully grown, pretty impressive. A couple of species can reach a leg span in excess of 10cm, which is more than big enough to give most people a scare.

The impression that these spiders are getting bigger could have a few explanations. The first is that, during the summer, these spiders are still growing and are not so conspicuous in our homes. By autumn, adult males start moving around looking for females and so we suddenly see larger spiders much more frequently. Couple this with the fact that many people are not exactly spider fans, and that house spiders may appear against pale carpets or white bathtubs then it is easy to see how people could think they are getting bigger.

It's also possible that people may be seeing different species of spider. If you are used to seeing the smaller *Tegenaria domestica*, the larger *Eratigena atrica* is going to come as something of a shock. Another possibility is that, since spiders are predators, a good summer for their prey species may mean that spiders are better fed and have more chance of reaching a larger size.

None of these explanations suggest that spiders are getting bigger. However, there is an intriguing piece of work from Australia that lends some weight to the idea that spiders could get larger, given the right circumstances. In the study, golden orb-weaving spiders living in and around Sydney were collected and measured. The researchers focused on mature adult females collected from a variety of sites ranging from city parks to bushland. They measured these spiders to assess body size and condition. They also dissected some of them to measure ovary size. What they found was that spiders in urban areas were significantly larger than those from less built-up areas. Not only were 'city spiders' bigger, they also had larger ovaries meaning they could lay more eggs.

It seems that two factors may have resulted in the larger urban spiders: temperature and prey availability. Buildings, concrete, tarmac and hard materials store up heat and make urban areas warmer. The warmer temperatures of urban areas could have increased spider growth rates.

Urban regions may also have more prey available for spiders, or it may be that spiders are building their webs in areas that happen to attract more prey. Street lighting is effective at attracting flying insects, and larger spiders were associated with structures like lampposts and were found in central areas with higher levels of lighting.

Whether other spiders are similarly affected by urbanisation remains to be seen. What is clear is that the habitats we create in our cities can have profound effects on the creatures that share our homes and gardens.

ILLUSTRATIONS: DANIEL BRIGHT

WHY DO I GET ANXIOUS THOUGHTS LATE AT NIGHT?

MANY OF US SUFFERED SLEEPLESS NIGHTS DURING THE PANDEMIC...

BY DR CHRISTIAN JARRETT

According to the Sleep Foundation in America, a conservative estimate is that 10 to 30 per cent of adults experience chronic insomnia or problems with sleeping. One common way this manifests is through difficulty falling asleep in the first place, especially due to anxious thoughts whizzing about. Indeed, a study from the University of Oxford found that a key difference between insomniacs and controls was the content of their thoughts at bedtime, with the problem sleepers being more focused on worries and concerns as compared with the healthy controls who tended to think about nothing in particular.

Anecdotally, many of us have had the experience of falling blissfully fast asleep in front of the TV, only to find that when we stir and take ourselves to bed, we lie there wide-awake with anxious thoughts racing through our minds. This common scenario neatly encapsulates one of the main reasons our heads fill with worry at night – it's the lack of distraction.

When you're busy during the day, your brain is occupied with all manner of tasks and activities, whether working, doing chores, talking to others or having fun. In the evening, you might eat dinner, chat and then watch TV – all the while, the brain is occupied, especially the regions involved in planning, decision making and other aspects of worry. Yet the moment you rest your head on your pillow and switch out the lights, all external distraction and engagement with the outside world is gone. Your mind is entirely free to turn in on itself, either to fret about all that's happened or to worry about the next day to come – the past and the future being the two main sources of anxious thoughts.

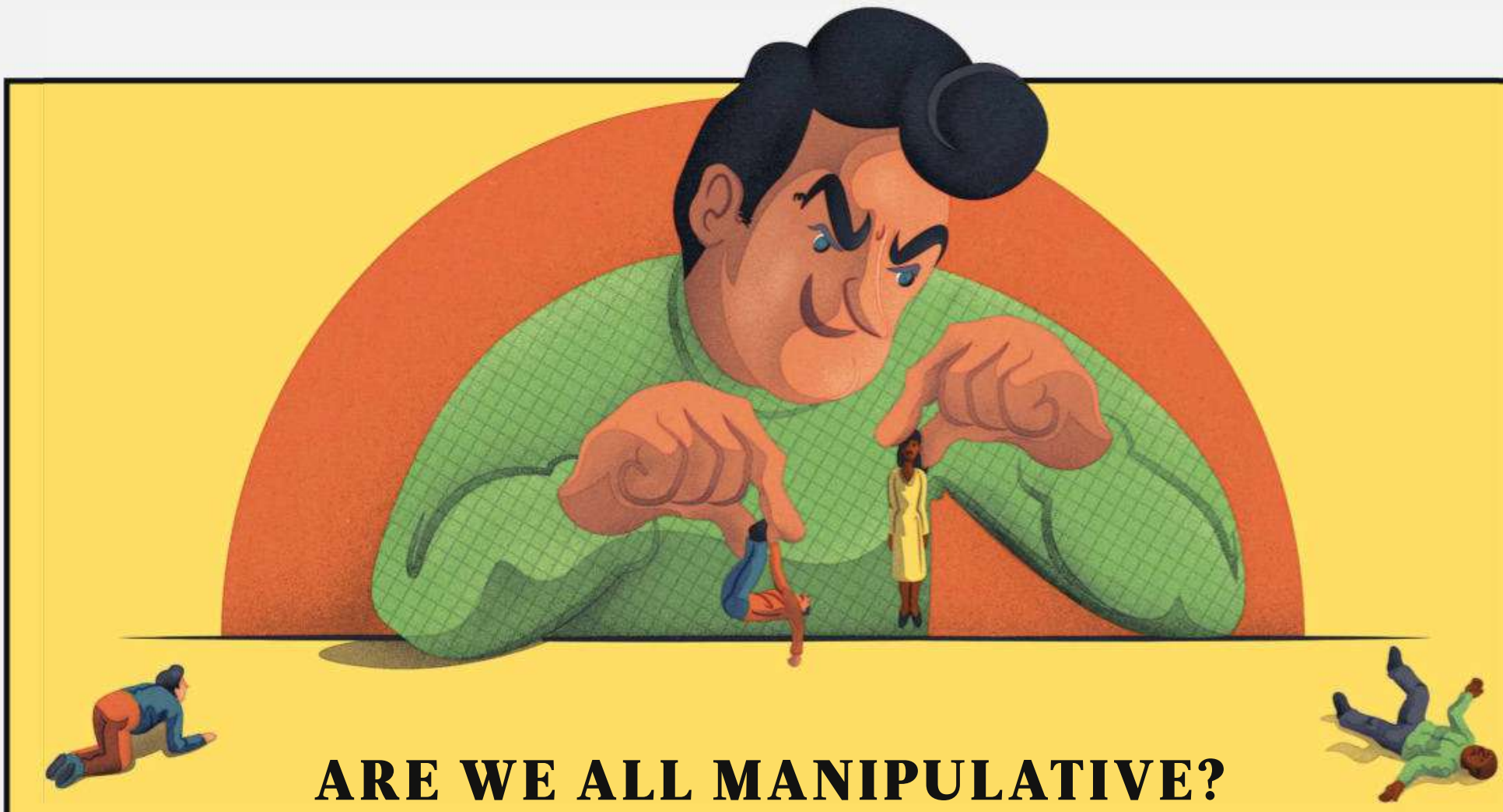
Psychologists are increasingly realising that one of the least effective ways to deal with intrusive, troubling thoughts is to try to fight them – doing so only increases their salience, making them hang around for longer. Instead, it's better to acknowledge and accept the thoughts, then let them pass.

For anxious thoughts about the day that you've just had, one practical way to do this is by writing an emotionally expressive daily journal before bed. A pair of researchers at the University of Oxford found that people with insomnia who spent time before bed writing openly about their worries and concerns subsequently took less time to fall asleep. It's as if the writing exercise got the anxious thoughts out of their heads and onto paper, making it easier to drift off.

For many people, it's not worries about the past that keep them awake, but worries about all that they have yet to do – indeed, there's some evidence that Sunday nights are the worse for insomnia for this reason, with a daunting week of tasks and deadlines looming ahead. If this fits with your own experiences, there's evidence that you too could benefit from getting those worries out of your head and onto paper.

For a paper published in 2018, researchers at Baylor University and Emory University School of Medicine asked participants at their sleep lab to spend five minutes before bedtime either writing about all that they'd done or all that they needed to do over the coming days – crucially, it was the latter group who fell asleep faster. "The key here seems to be that participants wrote their to-do list rather than mentally ruminated about their unfinished tasks," the researchers said.

Generally speaking, the research suggests that worry (in moderation) is a normal human activity. Rather than trying to fight it, the trick for a peaceful night is to plan a time earlier in the day to give your brain a chance to vent any anxieties. That way, when your head hits the pillow, you'll find it easier to sail off to dreamland on calm waters.



ARE WE ALL MANIPULATIVE?

TV PHENOMENON *SQUID GAMES* HAD US WONDERING WHETHER PEOPLE ARE THAT MANIPULATIVE IN REAL LIFE

BY DR JULIA SHAW

Emotional manipulation has been referred to as the dark side of emotional intelligence by psychological scientist Prof Elizabeth Austin at the University of Edinburgh. But what does that mean? Austin and her colleagues created the Emotional Manipulation Scale in 2007. According to the scale, people who are high on emotional manipulation say yes to behaving in ways that have obvious negative consequences such as 'I know how to embarrass someone to stop them behaving in a particular way', and 'I know how to play two people off against each other'.

Less obviously negative behaviours can also result in a high score, including agreeing with statements like 'I can pay someone compliments to get in their good books', and 'I am good at reassuring people so that they're more likely to go along with what I say'. The researchers also found that the higher people scored on the Emotional Manipulation Scale the higher they scored on Machiavellianism, a trait that includes being callous, morally indifferent and manipulative.

Framing manipulation as an inherently bad thing that is only done by bad people is, however, incorrect. There are many reasons why people want to massage a social situation so that it works out well for themselves that don't result in negative consequences for others. Self-interest can align with the interest of others and can lead to prosocial behaviour. For example, sometimes I do things to make other people feel good because I know it will make me feel good. It's win-win.

This complexity is also what Austin and colleagues showcased when in 2013 they pivoted from their original scale and created the Managing the Emotions of Others Scale.

Moving from the term 'manipulation' to 'managing' encourages a different way of talking about this type of behaviour. The most recent short version of the Managing the Emotions of Others Scale was published in 2018 by Austin and colleagues. It breaks down the diversity of ways in which people try to emotionally manage people into five types. The first two are generally prosocial, the third and fourth are non-prosocial, and the fifth is considered neutral.

Enhancing: strategically offering help, reassurance, or showing understanding to improve someone's mood.
Diverting: being positive or using humour to improve someone's mood.
Worsening: using criticism or negative comments, undermining confidence, or being angry to gain something.
Being inauthentic: flattering someone, sulking or guilt-tripping to get what you want.
Concealing: hiding how you really feel, particularly hiding negative emotions.

Using this concept of manipulation shows us that trying to influence how people around us feel is a core part of human interaction. Some of us are probably manipulating others on a daily basis.

Are some of us are better at manipulation than others? In 2020 Nguyen Ngoc and colleagues published a summary of research involving a total of 5,687 participants. They found that people higher on emotional intelligence scored higher on emotional manipulation. This means that being able to read the room and spot what people need is an advantage for manipulation. The question is what people do with this advantage. Being good at emotional manipulation "can be used to either help or harm people, depending on the manipulator's motivation," they wrote.

By accepting that we are all manipulative, we can better identify when we are manipulating people and therefore keep our motivations in check.

ILLUSTRATIONS: DANIEL BRIGHT

WHAT IS THE BOÖTES VOID?

SPACE IS FULL OF HOLES

BY DR ELIZABETH PEARSON

In 1981, Robert Kirshner was working with other astronomers at the University of Michigan to calculate the redshifts – a measure of how fast something is moving away from Earth – of a great number of galaxies. Due to the way our Universe is expanding, the farther away a galaxy is the faster it moves, meaning redshift can be used to measure distance. Kirshner and his team were taking advantage of this to create a 3D map of the Universe. As the map became fleshed out, something strange appeared. At 700 million light-years from Earth was a blank void. In a roughly spherical region around 330 million light-years wide – a region the Milky Way could fit into billions of times over – there were barely any galaxies.

Initially, the region was referred to as The Great Nothing, but later came to be known as the Boötes Void, as it appears to lie in the constellation of Boötes, the herdsman who drives the Plough around the North Pole.

Since then, surveys have managed to create more detailed maps of our Universe. We now know that galaxies are arranged like a giant web. The majority of galaxies in our Universe are found in long structures, known as filaments, that wind through the cosmos. When these meet, they create regions with a high concentration of galaxies, known as clusters. Between these threads, however, are huge empty voids with hardly any galaxies at all. The voids make up around 80 per cent of the observable Universe, and most are around 30 to 300 million light-years across. Boötes is one of the largest, earning it the title of 'supervoid'. It's thought that Boötes is the product of smaller voids merging together.

The cause of these voids is thought to lie in the origin of the Universe. In the early days of the cosmos, all the Universe's matter was tightly packed together. Initially, this is thought to have been a uniform soup, but random quantum fluctuations soon created small differences in the distribution of matter. Some areas were now slightly more dense, meaning their gravitational pull was greater so that they pulled matter away from the less dense areas. This made them even more dense, increasing their gravitational pull again so they attracted more matter and so on. At the same time, the Universe was expanding greatly and so these fluctuations that started on a quantum level eventually spanned hundreds of millions of light-years. Meanwhile smaller clumps of matter began to organise themselves into galaxies.

By studying these large structures, astronomers can gain a window into what the Universe looked like in its earliest moments. Today, advancements in both telescope and imaging technology mean they are able to create more detailed versions of Kirshner's maps, such as the Dark Energy Survey which has mapped out a quarter of the southern sky, examining around 300 million galaxies. Meanwhile, supercomputers can now create detailed simulations of how the Universe has grown from those first moments after the Big Bang to the cosmos we see today. By comparing these maps with the simulations, astronomers can begin to understand how our Universe came to look the way it does today.

DO FOUR-DAY WEEKS WORK?

BY ROB BANINO, FREELANCE EDITOR

On the face of it, yes. Trials in Iceland and New Zealand have seen reductions in employee stress levels, improvements in work-life balance scores and boosts in productivity. A 2019 trial at Microsoft in Japan reported a whopping 40 per cent increase (measured by sales per employee over the same period the previous year), as well as reductions in absences and electricity consumption.

But there's more to this than having Fridays off. Any changes need to be carefully managed if they're to increase efficiency. For example, Microsoft encouraged staff to limit any meetings they couldn't avoid to 30 minutes. Other companies have invested in tools to eliminate distractions, such as noise-cancelling headphones and 'do not disturb' lights.

There's also the matter of how that fifth day is lost: will wages be cut; will the length of workdays increase? What about sectors that operate 24/7, such as healthcare? Or people on zero-hours contracts?

The best option – for now – seems to be to make it as easy as possible for people to work as few hours as they need to fulfil their obligations and earn a liveable wage. Four-day weeks may allow that for some. A universal basic income might make it possible for more.

IS MY SOURDOUGH ACTUALLY UNIQUE?

IN PRAISE OF OUR FUNGAL FRIEND THAT WE ALL GOT TO KNOW A LOT BETTER DURING LOCKDOWNS

BY DR STUART FARRIMOND

Humans have been using yeast to make bread for at least 3,000 years. For most of that time we didn't understand a lot about it, let alone know how to purify and grow it. In fact, until the mid-1800s, few people even thought that yeast was a living creature.

Yeast is a type of fungus that grows pretty much everywhere – in soil, on leaves, plants, flowers, and it even floats around in the air. By happy coincidence, a handful of yeast types will 'eat' sugars and starches, turning them into alcohol (something we call fermentation) and belching out carbon dioxide gas. When some of our ancient ancestors experimented in their prehistoric kitchens by heating cereal grain in water with herbs to make a nourishing drink, they realised that the frothy liquid would turn into a type of beer, courtesy of yeasts that had been growing on the cereal. Mix some of this tangy slurry into a dough, bake it in an oven and you have discovered yeast-risen bread.

Nowadays, a highly productive strain of yeast (*Saccharomyces cerevisiae*), known as 'baker's yeast' or 'brewer's yeast' is purified, powdered, and sold en masse for making bread and many other baked goods. Much of modern bread's bland sameness is because the same yeast type is used everywhere.

But that's not to say you can't try wild strains, of which there are many. For hundreds of years, bakers would keep a batch of wet, frothy dough aside to use in their next batch of bread. This living slurry of continually reproducing micro-organisms (called a 'starter') has a unique blend of microbes that can be kept alive indefinitely by feeding, growing and passing down through generations.

Microbes from a baker's hands and the air are also infused into the starter, adding to its character and complexity. Acid-producing bacteria similar to those used in yoghurt-making are also typically in the mix, giving sourdough bread its distinctive tartness.

If you want to bake with wild yeasts (and their bacterial fellows) at home, you could either find a friend who has a sourdough starter and ask them to let you have some, or you make your own by thoroughly mixing equal parts flour (preferably organic) and water into a large clean jar, leaving it partly covered at room temperature and then repeating the process every day for four or five days, adding to the mixture each time until it becomes a bubbly, beery broth; at which point you can take some of it out to use in your bread recipe.

Yeasts need a regular dose of fresh flour as food so they can keep on multiplying, while the water gives their expanding numbers space to grow. Leave it at room temperature and forget to feed it for a few days and it will get progressively more alcoholic (the boozy liquid that pools on the top, called 'hooch', can be drained off). Without 'feeding', growth will stall, and yeast numbers will dwindle, reducing the rise it gives when used in baking. Yeasts are hardy though, and a forgotten starter can usually be revived with some fresh flour and water.

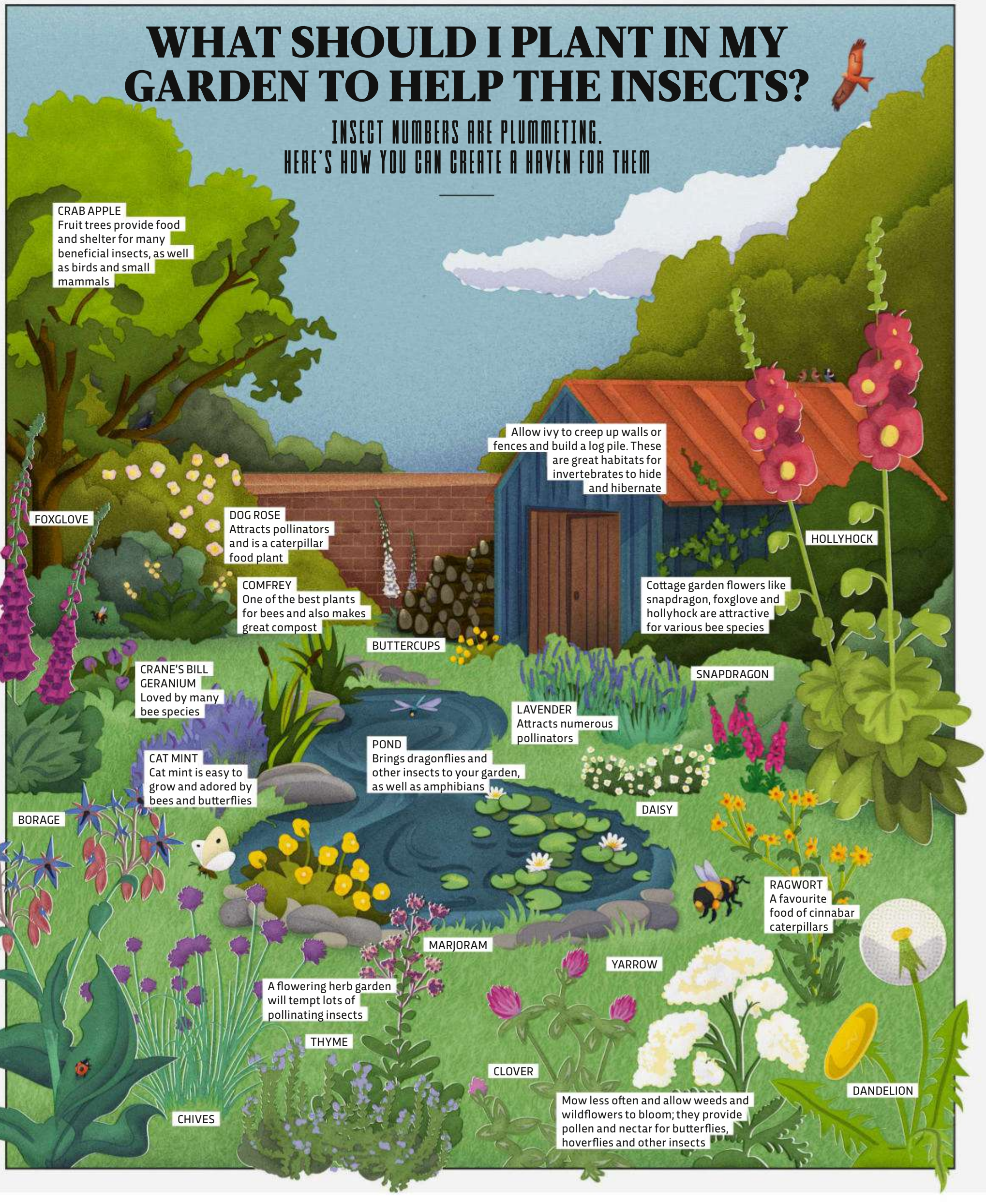
Most sourdough bread recipes call for 10-20 per cent of the total flour to be starter. Keeping your starter in a fridge slows down its growth, meaning you only need 'feed' it with flour and water every three or four days.

The 'proving' stage before baking, during which a kneaded dough is left in a warm place to allow the yeast to produce lots of gas bubbles, typically takes longer with wild yeasts than commercial strains. When you put your dough in a preheated oven, the carbon dioxide gas bubbles expand, giving the rise, and the yeast have one final surge in growth until they die and breathe out their last at 60°C. The yeast have come a long way, but they have done a good job.

GETTY IMAGES ILLUSTRATIONS: DANIEL BRIGHT

WHAT SHOULD I PLANT IN MY GARDEN TO HELP THE INSECTS?

INSECT NUMBERS ARE PLUMMETING. HERE'S HOW YOU CAN CREATE A HAVEN FOR THEM


CRAB APPLE
Fruit trees provide food and shelter for many beneficial insects, as well as birds and small mammals
Allow ivy to creep up walls or fences and build a log pile. These are great habitats for invertebrates to hide and hibernate
FOXGLOVE
DOG ROSE
Attracts pollinators and is a caterpillar food plant
HOLLYHOCK
COMFREY
One of the best plants for bees and also makes great compost
Cottage garden flowers like snapdragon, foxglove and hollyhock are attractive for various bee species
BUTTERCUPS
CRANE'S BILL GERANIUM
Loved by many bee species
SNAPDRAGON
LAVENDER
Attracts numerous pollinators
POND
Brings dragonflies and other insects to your garden, as well as amphibians
CAT MINT
Cat mint is easy to grow and adored by bees and butterflies
DAISY
BORAGE
RAGWORT
A favourite food of cinnabar caterpillars
MARJORAM
YARROW
A flowering herb garden will tempt lots of pollinating insects
THYME
CLOVER
DANDELION
Mow less often and allow weeds and wildflowers to bloom; they provide pollen and nectar for butterflies, hoverflies and other insects
CHIVES

COULD AEROPLANES GO GREEN?

AS WE RETURN TO HOLIDAYS, WE WONDER WHETHER WE CAN HAVE GUILT-FREE TRAVEL

BY ALEX FRANKLIN-CHEUNG

ILLUSTRATIONS: DANIEL BRIGHT

According to the World Economic Forum (WEF), aviation is responsible for 3 per cent of global carbon dioxide emissions. This may not seem like a lot, but while most economic sectors are shrinking their carbon footprint, aviation's is rising. Without significant action, the contribution to global emissions could soar to 22 per cent by 2050 as passenger numbers rise. In 2021, global airlines, convened by the International Air Transport Association (IATA), committed to reversing this trend to reach net-zero emissions by 2050. While greener air travel is possible, it will be a challenging task, particularly at a time when airlines are still reeling from the financial losses they have incurred during the pandemic.

Perhaps the most straightforward path to greener flights is to swap out traditional kerosene jet fuel for environmentally-friendly alternatives, known as sustainable aviation fuels (SAFs). SAFs are produced using cooking oil, household waste or plant matter, and can be blended in with kerosene to fuel existing planes without modifying their engines. Once you factor in production and transport, the use of SAFs can lead to 80 per cent less carbon emissions than the use of kerosene in a single flight.

Figures produced by the IATA show that almost 400,000 flights to date have already been powered by SAF. In 2021, 100 million litres of the fuel were produced. The catch? Sustainable fuels currently account for just 0.1 per cent of global consumption, and typically cost three times more than conventional fuels. Although production is ramping up, there is still a long way to go. In time, and with enough government support, the IATA estimates that more widespread use of SAFs could enable a 65 per cent cut in aviation's overall emissions, but they are just one piece of the puzzle.

Going electric is an obvious route to making transport more sustainable. With an increasing proportion of electricity coming from low-carbon sources such as wind or solar power, electric vehicles can dramatically cut the carbon emissions linked to travel. But electric planes face one considerable hurdle: weight. While a kilogram of jet fuel packs away 12,000Wh of energy, a lithium-iron battery only manages 250Wh per kilogram.

What's more, while a traditional plane gets lighter as it burns up its fuel, batteries offer no such savings. This makes electric long-haul flights a non-starter for the foreseeable future – any plane with sufficient battery power for long-haul flights would simply be too heavy to take to the skies. Instead, a raft of companies are focusing on smaller planes that could travel on shorter routes, or hybrid models where electricity complements a traditional engine. Budget airline easyJet, for example, is currently developing a fully electric plane capable of carrying 186 passengers, which it hopes could cover short routes such as London to Amsterdam from 2030.

Elsewhere, hydrogen has been heralded as the clean energy source of the future, with its combustion releasing only water vapour. Hydrogen aircraft can either burn hydrogen directly as a fuel, or use it to generate electricity using hydrogen fuel cells. In 2020, ZeroAvia retrofitted a six-seater plane and flew the first passenger flight powered by hydrogen fuel cells. But hydrogen comes with its own set of challenges. Although by weight, hydrogen holds more energy than jet fuel, it takes up a much larger volume, even when cooled into a liquid state. To generate the same amount of power as a standard plane, a hydrogen jet would need a fuel tank four times the size, leaving less space for passengers or freight.

Additionally, although hydrogen can be produced with near-zero emissions, the majority of hydrogen used today is derived from natural gas, using a process that releases CO_2. The success of hydrogen-powered flight would also be reliant on developing a 'hydrogen economy': the wide-ranging global infrastructure required for hydrogen to be produced cleanly, stored and transported around the world.

WHAT IS THE CARBON FOOTPRINT OF A 4K NETFLIX BINGE?

DIGGING INTO THE CARBON IMPACT OF DIGITAL STREAMING

BY DR PETER BENTLEY

We're streaming more and more of the content that we watch – an Ofcom survey found that video-streaming services and other non-broadcast content were up 70 per cent more in 2020 compared to 2019. But what impact does this activity have on the environment? There's no single answer to this question, but we can make a few assumptions and scribble on the back of an envelope to figure something out. (There has been some controversy about these kinds of numbers – here we'll use the detailed estimates made by **carbonbrief.org**.)

First, what are we going to watch on our marathon binge? Let's pick one of the highest rated shows of all time: *Breaking Bad*. That's 3,678 minutes, or about two and a half days of solid viewing, assuming no adverts and assuming we watch every precious second.

Different countries have different energy sources, so if we binged from our holiday home in France, where about 90 per cent of electricity is generated by low-carbon sources, we'd have a smaller carbon footprint compared to UK. This time, let's watch from the UK. If we watch on different devices, then we will affect our carbon footprint – a mobile device can use 100 times less energy compared to a TV. Nevertheless, Netflix estimates that 70 per cent of their content is viewed on a TV, so let's use that – we want to get the full cinematic effect of *Breaking Bad*. If we streamed our show via 4G or 5G then this would also affect our carbon footprint. So, let's use good old broadband, which should be slightly more efficient. However, let's say our TV is a nice big 50-inch 4K model which uses more power and we'll be streaming a larger amount of data to get that beautiful high-resolution picture.

Estimates by Carbon Brief have shown that for 2019, the data centre that stores the data was likely to use about 0.0139kWh (that's kilowatts per hour), transmission of the data would be about 0.0188kWh, and our big 4K TV would use about 0.1200kWh, equating to a total of 0.1527kWh, or 71.49g of CO_2 per hour. Though this may be less since large data centres often procure cleaner energy compared to average – another estimate by the Carbon Trust puts the figure closer to 55g CO_2 per hour on average in Europe. But let's stick with our numbers. Our full binge of *Breaking Bad* would come to 61.3 hours at 71.49g CO_2 per hour, so a total of 4.382kg of CO_2. In comparison, a typical electric car in the UK emits about 100g CO_2 per kilometre (battery uncertainty and different models give some differences here), so that means you could have driven about 44km (27 miles) for the same carbon emissions as watching the show.

It's worth noting that all of these numbers are likely to change over time, and should become lower as our technologies improve. We're also likely to become ever better at estimating our impact on the environment. In fact, computer scientists at Bristol University have created a tool called DIMPACT, which aims to estimate the carbon footprint of digital video, games and music streaming, as well as publishing, advertising services and business intelligence. Netflix, BT and Cambridge University Press have already signed up to use DIMPACT, with others likely to follow suit in the near future.

So maybe one day we will have a complete and accurate breakdown of the environmental impact of every activity that takes our fancy. But for now, based on the numbers we have today, it looks like watching a high school teacher put his chemistry knowledge to dubious use on TV for two and a half days straight, is way better for the planet than going for a quick drive.

ARE ASIAN HORNETS INVADING THE UK AND EUROPE?

WATCH OUT, HONEYBEES

BY DR ADAM HART

The first thing it is important to make clear is that when we talk about Asian hornets we are using a 'common name'. Common names can cause confusion. For example, when someone in the UK calls a bird a 'robin' they are referring to the small, crimson-breasted bird on Christmas cards, but in the USA 'robin' refers to a larger species of thrush. Likewise, 'Asian hornet' is often applied to two species of large social wasp. Only one of these species is relevant to Europe, but both hornet species are invasive.

The species we are concerned with in Europe has the scientific name *Vespa velutina*. The other species commonly called the Asian hornet (more correctly Asian giant hornet) is the larger *Vespa mandarinia*. This species is found in many parts of Asia but has recently been discovered in the Pacific Northwest of North America. The hornet's size (4.5cm long, 7.5cm wingspan and a 6mm sting) and fears that it may become invasive in North America have led to the media calling them 'murder hornets'. These are impressive insects, and may become an issue in North America, but they are not the Asian hornets that concern us.

Hornets are social wasps. They live in colonies that consist of as many as a few thousand workers, each of which is the daughter of the single queen that starts the colony in the spring. The colony is housed in a paper-based nest made by the hornets from wood pulp they collect and manipulate with their jaws. Like other social wasps, including the native European hornet *Vespa crabro* that is naturally found across the southern UK, *Vespa velutina* is a predator. Although they will hunt many insects, it is their strong tendency to specialise on honeybees that makes *Vespa velutina* a problem when it is found in new areas.

The Asian hornet's natural range is Southeast Asia. However, they were accidentally introduced into France in 2004, quite possibly in boxes of pottery from China. In the hornet's natural range, the most common species of honeybee has some great defences against the hornets. For example, any hornets that try to enter the honeybee nest will be 'balled' by guard bees, which surround the hornet and cause it to overheat. Honeybees in Europe, though, have poor defences.

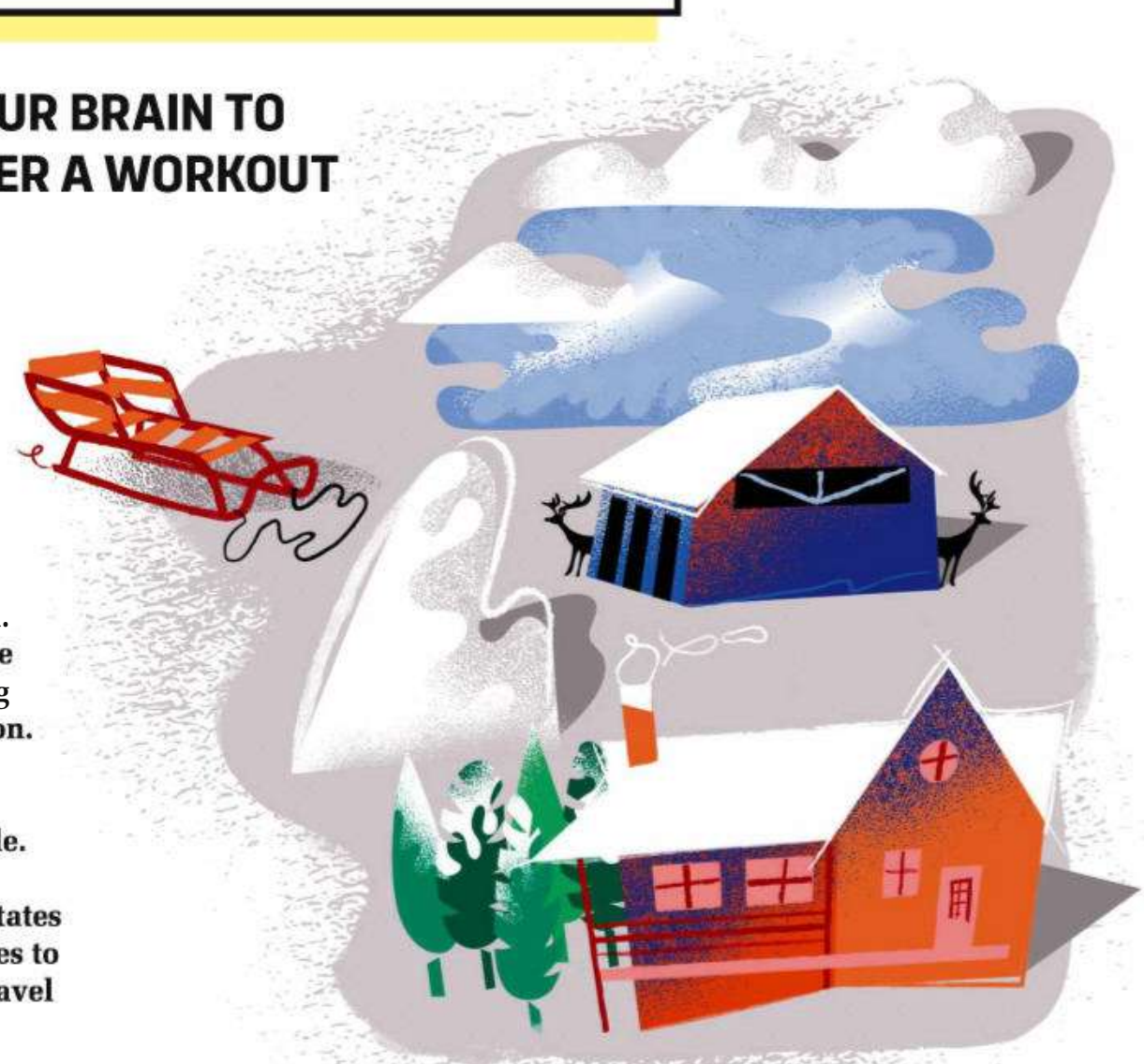
The Asian hornet spread quickly after it was introduced. By 2015 they were found over most of France. They also spread to neighbouring countries, reaching Spain by 2010, Portugal by 2011, Italy by 2012, Belgium by 2017, and Ireland by 2021. They were discovered in mainland UK in 2016.

Right now, Asian hornets are not considered to be established in the UK. Beekeepers have been on high alert for over a decade and through local Asian Hornet Teams and the National Bee Unit, nests are tracked down when new sightings are made. It is thought that the incursions originate from queen hornets that have 'stowed away' in caravans and vehicles travelling from Europe. The Channel is helping to keep the Asian hornet at bay in the UK, but with reports and sightings growing, it is perhaps just a matter of time before they do become established. SF

ILLUSTRATIONS: DANIEL BRIGHT

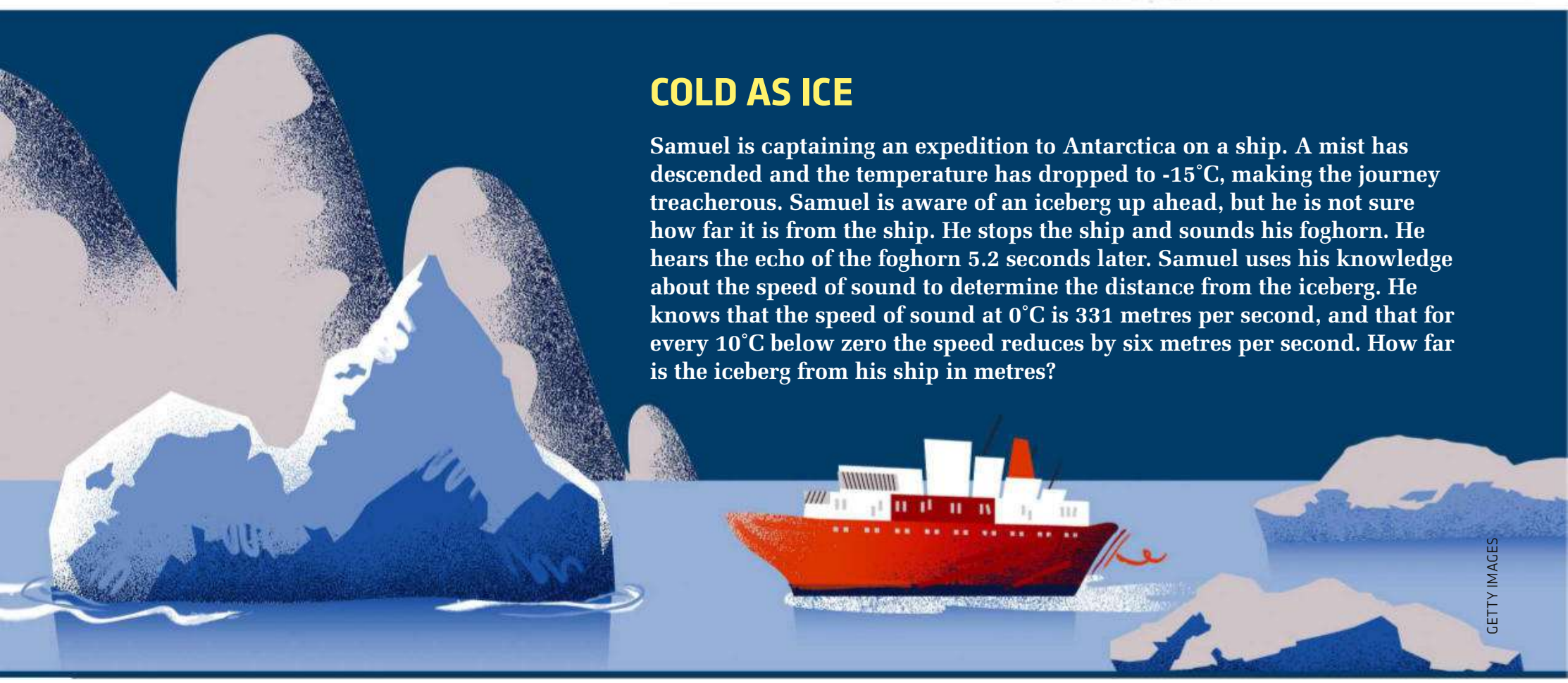
BRAIN GAMES 2021

CHRISTMAS TELLY TURNED YOUR BRAIN TO MUSH? GIVE THAT GREY MATTER A WORKOUT WITH THESE TRICKY PUZZLES



SNOWED IN

Nick and his sleigh are stranded in the woods. He is desperate to get back to his cabin in time for Christmas to deliver presents to his children. His usual route would take him in a straight line directly to his cabin, but a snow drift is blocking his way. Instead he must take a lengthy diversion. Nick sledges three kilometres east to the frozen lake, before turning his sleigh 135° clockwise and travelling 1,300 metres to the reindeer stable. According to his sat-nav he is now 500 metres further south than the frozen lake. Nick then rotates his sleigh 45° clockwise, and travels 1,275 metres to his cabin. How much further has Nick had to travel due to the diversion?



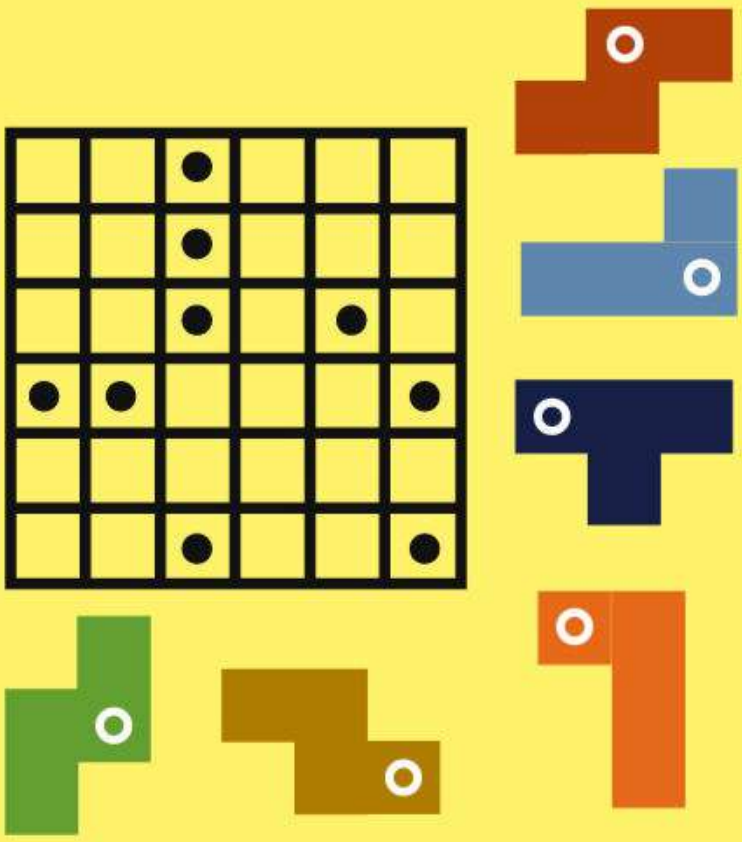
COLD AS ICE

Samuel is captaining an expedition to Antarctica on a ship. A mist has descended and the temperature has dropped to -15˚C, making the journey treacherous. Samuel is aware of an iceberg up ahead, but he is not sure how far it is from the ship. He stops the ship and sounds his foghorn. He hears the echo of the foghorn 5.2 seconds later. Samuel uses his knowledge about the speed of sound to determine the distance from the iceberg. He knows that the speed of sound at 0˚C is 331 metres per second, and that for every 10˚C below zero the speed reduces by six metres per second. How far is the iceberg from his ship in metres?

GETTY IMAGES

SQUARE UP

Fill the grid using the six coloured shapes. Leave no square blank. You may reuse any shapes, and you may rotate them but not flip them. Each shape has a symbol marked on it. The symbols must line up with the ones shown in the grid.



SPACE RACE

Three of the crew on the International Space Station are playing around with miniature spacecraft, aiming them at a target. Alan launches his craft at 1 metre per second (m/s), but doesn't turn the engine on. At the same time, Bernice launches her craft at 0.5m/s and has its engine on, accelerating the craft at 0.1m/s per second. The two ships hit the target at the same time. Chester knows that $s = ut + 0.5at^2$, where s = distance, u = initial speed, a = acceleration and t = time. If Chester launches his ship with no initial speed, how much acceleration will it require to take the same amount of time as the other ships did to hit the target?

ILLUSTRATIONS: CHRISTINA KALLI

SUDOKU

ANSWERS

Find answers to the puzzles and quiz on page 77. For the sudoku solution, visit **sciencefocus.com/magazine/christmas-puzzles-2021**

6		5			2			8
			1				7	
	9					6		
		2	7		6		8	
			4		5			
	3		9		1	7		
		4					9	
	5				4			
3			8			1		2

WORD GAMES

1. Rearrange the letter groups to make three sciences:

HAN ORO MEC OGY HYD ICS PHY GRA ROL

2. Crack the code to find three sciences:

GNTQTLD, GTYFSD, LJTQTLD

3. Rearrange the letter groups to make three fields of science:

ENY ROL PHY LOG AST OMY HYD OGY RON

CHRISTMAS QUIZ

1. Researchers from Denmark hooked volunteers up to heart-rate monitors to see how they reacted to... what?

a. Visiting a haunted house
b. Scrolling on Twitter
c. Doing a jigsaw puzzle

2. Scientists at MIT have developed a new cooling material that could keep things cold without a power supply. What inspired the material?

a. Camel fur
b. Penguin feathers
c. Elephant ears

3. A study of almost 2,000 UK adults found that those who did this activity regularly experienced less cognitive decline. Was it:

a. Watching Netflix
b. Eating cheese
c. Doing bicep curls

4. What did Kenyan conservationists build to rescue eight endangered Rothchild's giraffes from an island?

a. A bridge
b. A hang-glider
c. A raft

5. What part of Guinea baboon communication did researchers at the German Primate Centre study this year?

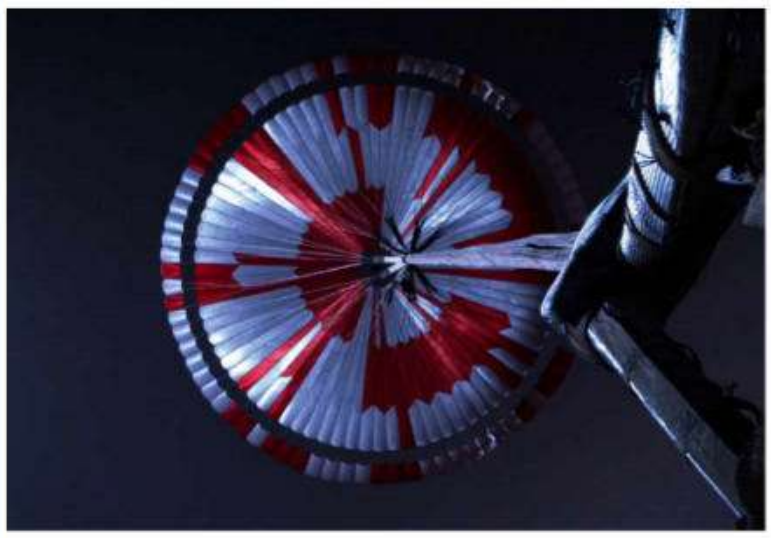
a. Their accents
b. The colour of their bottoms
c. The way they bare their teeth

6. This year, scientists observed electric eels in the Amazon teaming up in groups of up to 10 to hunt. They discharged a synchronised electric shock to their prey – but how many volts of electricity could 10 eels produce?

a. 86V
b. 860V
c. 8,600V

7. When NASA's Perseverance rover arrived on Mars, it deployed a colourful parachute containing a coded message, shown here. What did it say?

a. Per aspera ad astra
b. Dare mighty things
c. To infinity and beyond



8. Three missions arrived at Mars in February this year. Which was the first to arrive?

a. NASA's Perseverance
b. China's Tianwen-1
c. The UAE's Hope

9. Which 1990s hit did neuroscientist and DJ Rebecca Poulsen play to baby zebrafish to monitor their brain activity?

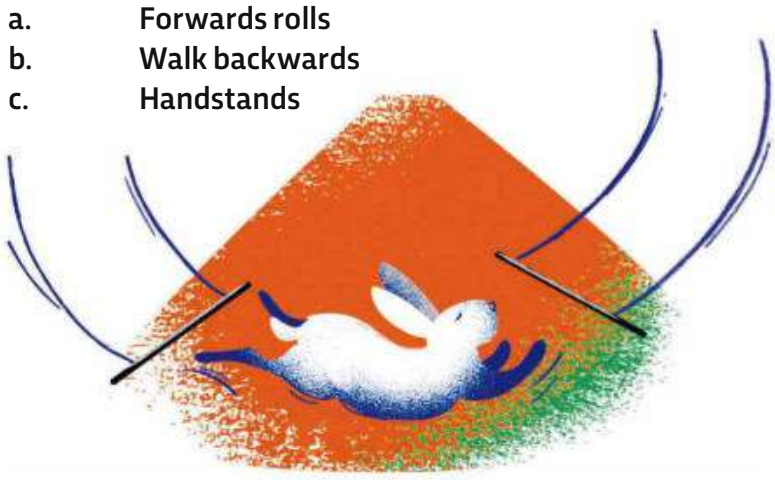
a. Wannabe
b. U Can't Touch This
c. Livin' La Vida Loca

10. What space weather phenomenon, first observed over the North Pole in 2014, was confirmed this year?

a. Space hurricane
b. Space tornado
c. Space monsoon

11. The sauteur d'Alfort rabbit has a gene, discovered this year by researchers in Portugal and Sweden, that explains the breed's tendency to do what?

a. Forwards rolls
b. Walk backwards
c. Handstands



12. Researchers in Costa Rica discovered that spreading the pulp leftovers from a particular industrial process over land set aside for reforestation led to the trees growing four times faster. But what product was the pulp from?

a. Beer
b. Coffee
c. Sugar

13. Russian scientists etched a mini replica of which beloved painting using a 'laser paintbrush'?

a. Mona Lisa
b. The Starry Night
c. Girl With A Pearl Earring

14. In March, 15 volunteers ventured into a cave beneath the Pyrenees, and didn't see natural light or a clock until they came back out. They stayed in the cave for so long that they lost track of how many days had passed. How many was it?

a. 20
b. 40
c. 60

15. In a somewhat unusual experiment, Japanese scientists have discovered that some mammals (possibly including humans) can breathe through which body part?

a. Ear
b. Anus
c. Belly button

16. After 17 years underground, 'Brood X' cicadas emerged in June across 15 states in the USA. How many of them were there?

a. Hundreds of thousands
b. Millions
c. Billions

17. *Homo longi*, a hominin identified this year, may be the closest ancestor of our species. What is its other name?

a. Unicorn Man
b. Dragon Man
c. Centaur Man

18. This year, scientists discovered bizarre DNA structures that assimilate genes from host cells. What sci-fi villain were they named after?

a. The Borg
b. Cybermen
c. Body Snatchers

19. The Met Office predicted this year that, by the end of the century, Britain could regularly see summer days at what temperature?

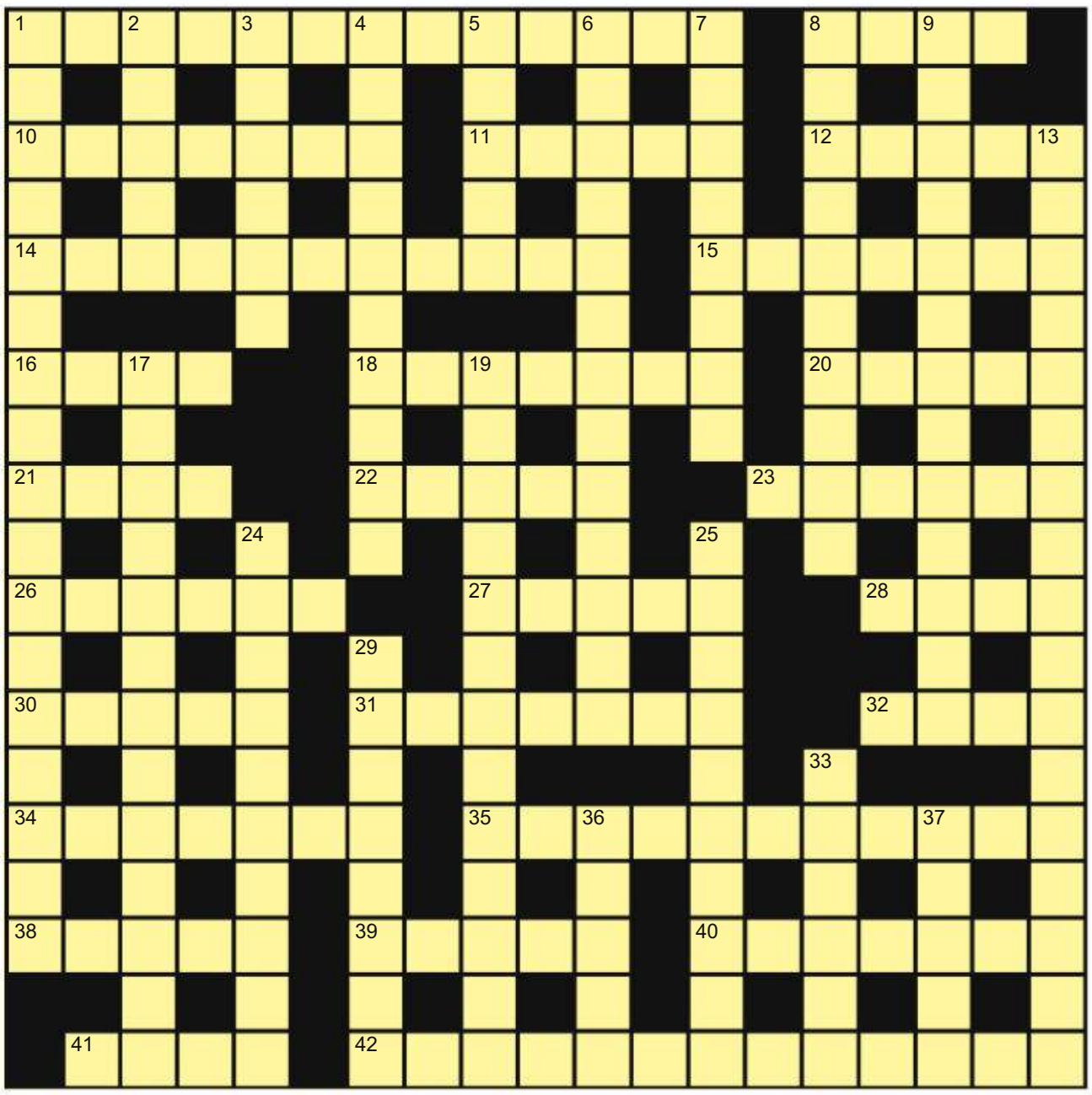
a. 35°C
b. 40°C
c. 50°C

20. In October, the World Health Organization recommended the rollout of a world-first vaccine to African children for which disease?

a. Malaria
b. Yellow fever
c. Dengue

NASA/JPL ILLUSTRATIONS: CHRISTINA KALLI

GENERAL KNOWLEDGE CROSSWORD



DOWN

1 Places where wildlife is protected (12,5)
2 A member of a wandering pastoral community (5)
3 An uncommon thing or incident (6)
4 A gelatinous mass of cyanobacteria once thought to be of meteoric origin (6,4)
5 Partial darkness (5)
6 Possibly the smallest lizard known to science (4-9)
7 Clear, bright green precious stones (8)
8 Border between Earth's atmosphere and outer space named after a Hungarian born physicist (6,4)
9 A cell found in the muscle of the heart (13)
13 Usually the last stage of production in e.g. sodium (17)
17 Most fungi are these type of organisms (13)
19 The practice of capturing, storing, processing and analysing data near the client (4,9)
24 A bear native to south central China (5,5)
25 US aviator Ed Yost was a pioneer in this activity (10)
29 A society in the US for the singing of choral music (4,4)
33 Another term for advanced or modernistic (2-4)
36 An injection of fluid into the lower bowel e.g. to introduce drugs (5)
37 A slang term in the US for an agent who enforces laws on the illicit production of drugs (5)

ACROSS

1 The property of an object moving away from the middle of rotation (13)
8 Robert, German physician who was a founder of bacteriology (4)
10 A symbol used to express a quantity (7)
11 Another name for the snow leopard (5)
12 Boy's name that derives from the Irish for 'red king' (5)
14 Warm-blooded (11)
15 An amino acid that is a common constituent of proteins (7)
16 Part of a boot or shoe covering the front of the foot (4)
18 Alan, the first US astronaut to travel in space (7)
20 A boundary or restriction (5)
21 A granular or compact mineral found in magnesium-rich rocks (4)
22 Non-flowering aquatic plants that include seaweed (5)
23 Latin expression meaning 'entirely' (2,4)
26 On the ____ of Species, work on evolution by Charles Darwin published in 1859 (6)
27 The prehensile claw of an arthropod such as a crab (5)
28 ____ disease, a virus transmitted to humans by ticks, affecting the joints, heart and nervous system (4)
30 International organisation founded in 1967 to which Indonesia among others belongs (5)
31 Relating to the threshold of consciousness (7)
32 The brightest star in the constellation of Lyra (4)
34 An obscuration of the light of the Sun or Moon by the intervention of another body (7)
35 Impassive or not showing feelings (11)
38 ____ goose, another name for the northern gannet (5)
39 The longest river in France (5)
40 Mistakenly (2,5)
41 A large black and white killer whale (4)
42 Prevailing model by which astronomers explain the beginning of the Universe (3,4,6)

ANSWERS

Find the crossword solutions at **sciencefocus.com/magazine/christmas-puzzles-2021**

CAROL'S CONIFERS

Carol's Christmas Barn stocks three types of Christmas tree. Scots pines are sold for £25 each, while Norway spruces and Douglas firs **are sold for 80% and 50% of this** price respectively. Despite the relatively high price, Scots pines are by far the most popular tree thanks to their high needle retention and fresh fragrance. Carol sold 10 more Scots pines than Douglas firs in the first week alone. In her first week of opening this year she made £1,195, not quite reaching her target of £1,200, but still a satisfactory amount from 59 trees. How much of this money did Carol make from selling Norway spruces?

SCIENCE CLASS

Four siblings are fighting over their toy science kit. Florence has the Bunsen burner and the test tube until Marie snatches one off her. Stephen wants to swap the goggles for the tongs or the Bunsen burner. Marie refuses to swap, but Albert is happy to. Who ends up with what?

WHAT SUBJECT?

Four friends are each starting one of these A-levels this week. Can you match them up? Aidan isn't taking a language, and Dean isn't taking a science subject. Chris went for Physics ahead of Chemistry. Brenda had an easy choice as she'd always preferred German to French.

ILLUSTRATIONS: CHRISTINA KALLI

SOLUTIONS

SNOWED IN

Solution: 4,850m

Explanation: Nick has travelled three sides of a trapezium. He moves 1,300m between the frozen lake and the reindeer stable, which is 500m further south. A right-angled triangle can be formed using 1,300m as the hypotenuse. Using Pythagoras' theorem it can be determined that the reindeer stable is $\sqrt{(1{,}300^2 - 500^2)}$ = 1,200m further west than the frozen lake. Nick's cabin is 3,000 - (1,200 + 1,275) = 525m further east from where he started. We know that his cabin is at the same latitude as the reindeer stable, 500m further south than the frozen lake and his starting point. A second right-angled triangle can be formed. The direct route to Nick's cabin is $\sqrt{(500^2 + 525^2)}$ = 725m.

Nick has travelled (3,000 + 1,300 + 1,275) - 725 = 4,850m further due to the diversion.

COLD AS ICE

Solution: 837.2 metres

Explanation: At – 15˚C the speed of sound is:

331 – (1.5 × 6) = 322 m/s

Samuel hears the echo 5.2 seconds later, so the sound of the foghorn took 2.6 seconds to reach the iceberg.

322 × 2.6 = 837.2 metres

SQUARE UP

SPACE RACE

Solution: 0.2 metres per second per second

Explanation: The equation for Alan's craft is: $s = 1t + 0t^2$. The equation for Bernice's craft is $s = 0.5t + 0.05t^2$. The ships travelled the same distance and took the same time, so s and t are the same in both equations.

We can combine them to get:

$t = 0.5t + 0.05t^2$
$1 = 0.5 + 0.05t$
$0.5 = 0.05t$

t = 10 seconds and therefore s = 10 metres.

To get Chester's craft to take the same time, use the equation again:

$10 = 0t + 0.5at^2$
$10 = 0.5at^2$
$20 = at^2$
$20 = a \times 100$
$a = 20/100 = 0.2$ metres per second per second

WORD GAMES

1. Hydrology, mechanics, orography
2. Biology, botany, geology (A becomes V, B becomes W, etc)
3. Astronomy, hydrology, phylogeny

CHRISTMAS QUIZ

1 A **2** A **3** B **4** C **5** A **6** C **7** B **8** C **9** B **10** A **11** C **12** B **13** B **14** B **15** B **16** C **17** B **18** A **19** B **20** A

CAROL'S CONIFERS

Solution: £420

Explanation: Assign the letters N, S and D to represent the number of each type of tree. N = Norway spruce, S = Scots pine, D = Douglas fir. Three equations can now be made:

1) N + S + D = 59
2) 20N + 25S + 12.5D = 1,195
3) S = D + 10

Substitute 3 into 1:

N + D + 10 + D = 59

N = 49 - 2D

Then substitute this equation into 2:

20(49 - 2D) + 25(D + 10) + 12.5D = 1,195
1,230 - 2.5D = 1,195
D = 14, S = 24, N = 21

Carol therefore would have made 21 x £20 = £420 from selling Norway spruces.

SCIENCE CLASS

Albert gets the goggles, Stephen the tongs, Marie the Bunsen burner and Florence the test tube.

WHAT SUBJECT?

Aidan is taking Chemistry, Brenda is taking German, Chris is taking Physics and Dean is taking French.

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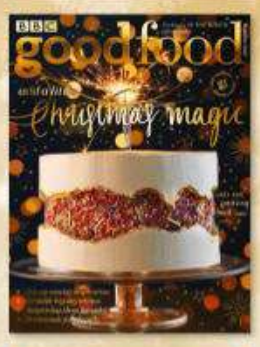
FOOD



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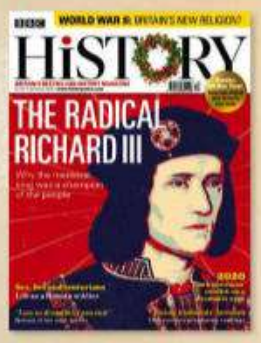

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SPORT

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Q&A

YOUR QUESTIONS ANSWERED

... WHAT WOULD HAPPEN TO MY SPERM IF I HAD A VASECTOMY?
... WHY DOESN'T EARTH HAVE RINGS?
... WHICH IS MORE HYGIENIC: PAPER TOWELS OR HAND DRYERS?
... HOW IS CAFFEINE REMOVED FROM DECAFFEINATED COFFEE?
... ARE ELECTRIC CARS GREENER THAN PETROL?
... WHAT IS A WORMHOLE?
... ARE YOU MORE LIKELY TO GET CHEST INFECTIONS IF YOU'VE GOT NO TONSILS?
... WHAT WERE THE SPINAL PLATES ON *STEGOSAURUS* FOR?
... HOW DOES GEOTHERMAL ENERGY PRODUCE ELECTRICITY?

Email your questions to

questions@sciencefocus.com

or submit on Twitter at

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Medical expert and GP trainee

LUIS VILLAZON
Science and technology writer

ILLUSTRATION: DANIEL BRIGHT

SAM DOYLE, BELFAST

IS IT HEALTHIER TO EKE OUT MY CHRISTMAS CHOCOLATES, OR EAT THEM ALL IN ONE MASSIVE BINGE?

If healthy people binge for one day the body will work a bit harder to deal with the calories and it is unlikely to cause weight gain. Making chocolates last a bit longer may be more damaging to the waistline, but there are positive aspects to daily chocolate consumption. Perhaps unsurprisingly, a Nestlé study of 90 Dutch people in 2012 suggested that eating chocolate every day may reduce anxiety levels. A number of studies point to potential health benefits of regularly eating small amounts of dark chocolate, including lower blood pressure and cholesterol levels. So, consider asking Santa for dark chocolates and eke them out. ***ED***

NATURE'S WEIRDEST CREATURES...

THISTLEDOWN VELVET ANT

This creature is a misnomer wrapped in a cloak of punky, white fuzz. It's a misnomer because the unusual critter is not an ant, it's a parasitic wasp that's native to the desert regions of the American Southwest. The white, fluffy females are wingless, and so superficially ant-like. In contrast, males have wings and a classic wasp livery of orange and black. This vibrant attire warns potential predators that the wasps are not to be crossed – velvet ants have one of the longest stingers (relative to body length) of any bee or wasp. However, the female's appearance has been something of an enigma. Females look like the fuzzy seeds of the scrubby creosote bushes that grow where the wasps live, so experts had presumed that the insects had evolved their appearance as a form of camouflage. But genetic analyses revealed that the wasps preceded the arrival of the creosote bush to the American Southwest by around five million years. Cue experiments placing white-coloured and vibrantly-coloured ants under heat lamps, and it seems that the female's white spiky coat helps it not to overheat. Proof, beyond doubt, that the punk look remains as cool today as it ever was! ***HP***

ADAM JOHNSON, LEEDS

WHICH IS MORE HYGIENIC: PAPER TOWELS OR HAND DRYERS?

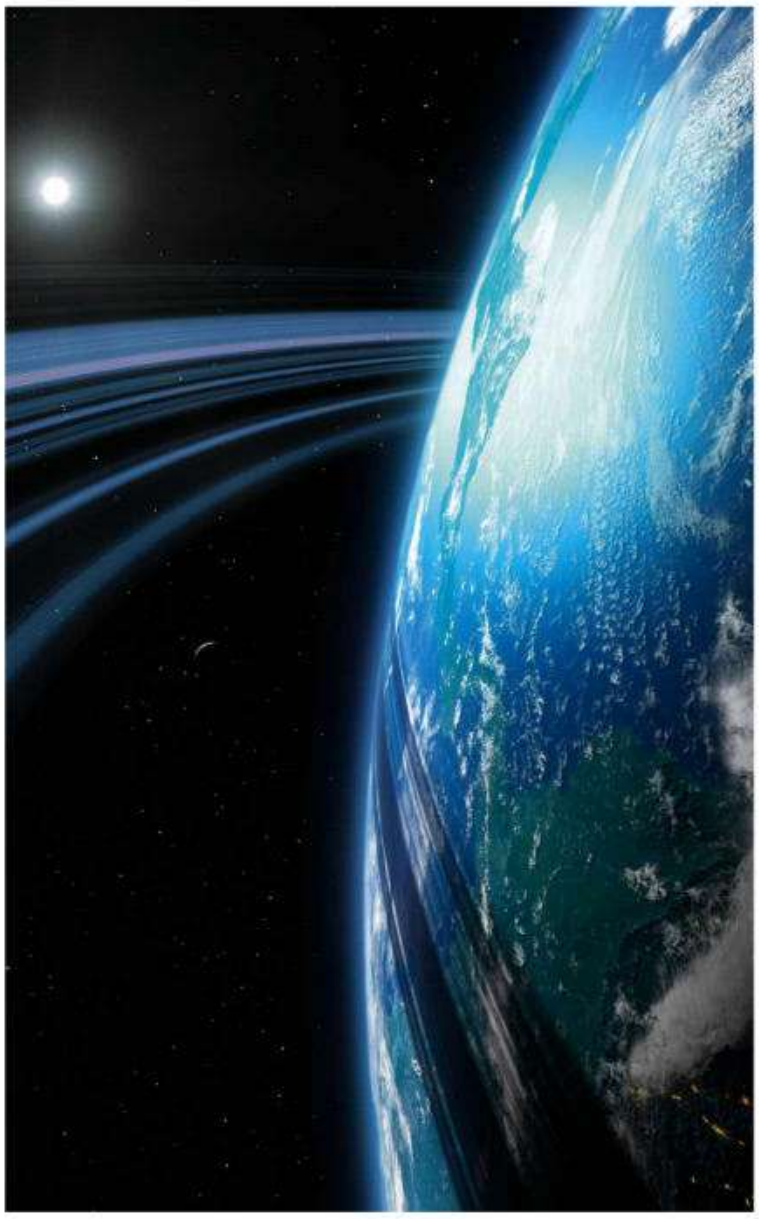
Although headlines on the hygiene of paper towels versus hand dryers might be seductive, scientists have tried and failed to come to a definitive consensus about which is really superior. When you look at the studies behind the headlines, you'll often find they are funded by the paper towel or hand dryer industry. It's difficult to compare the studies too, as airblowers vary in efficiency, and paper towels vary in thickness.

In truth, it probably doesn't matter much. What's more important is washing your hands regularly, with soap and water for 20 seconds, then using whatever is available to dry them. ***NM***

CARMEN WINSTEAD, HIGH WYCOMBE

HOW IS CAFFEINE REMOVED FROM DECAFFEINATED COFFEE?

The original process, developed by Ludwig Roselius in 1903, used benzene to dissolve the caffeine from the unroasted beans. Benzene is carcinogenic, so it has since been replaced with much safer solvents including dichloromethane and ethyl acetate, which evaporate when the beans are roasted. High pressure CO_2 is also used by mass market brands as an alternative to organic solvents. A third system, used primarily in the US and Canada, is the Swiss Water Process. This passes very strong coffee solution through a carbon filter to remove the caffeine, and then uses this solution to remove the caffeine from unroasted beans by diffusion, without damaging their subtle flavour compounds. ***LV***



MOE MBAGO, LONDON

WHY DOESN'T EARTH HAVE RINGS?

All gas giant planets (Jupiter, Saturn, Uranus and Neptune) in the Solar System have rings, while the terrestrial ones (Mercury, Venus, Earth and Mars) do not. There are two theories about how ring systems develop. They may have formed from leftover material from the formation of the planet, or be the remains of a moon that was destroyed by an impact, or was simply broken apart by the gravitational tugging of its parent.

It is unclear why only the gas giants have rings. However, the fact that gas giants formed in the outer Solar System, while rocky planets formed only in the inner Solar System may be a clue. Perhaps the inner planets were shielded from the collisions that could have formed rings, or perhaps the higher incidence of moons in the outer Solar System means rings also became more common there. Another factor may be that larger planets simply have a larger volume in which a ring system can form and remain stable.

Scientists believe the Earth did have a ring system in the past. Very early in its history a Mars-sized object collided with the Earth, probably resulting in a dense ring of debris. However, unlike the outer planets, Earth's ring system soon coalesced to form the Moon. ***AG***

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DEAR DOCTOR...

HEALTH QUESTIONS DEALT WITH BY *SCIENCE FOCUS* EXPERTS

WHAT WOULD HAPPEN TO MY SPERM IF I HAD A VASECTOMY?

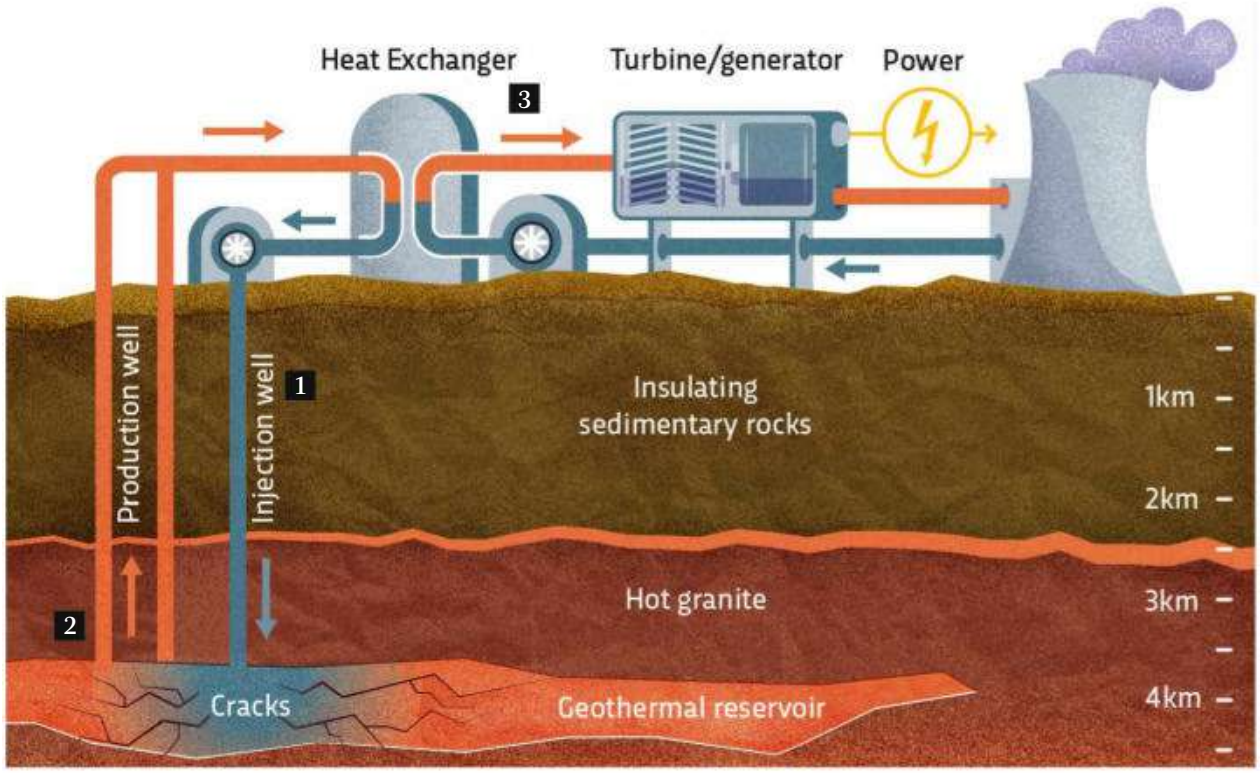
During a vasectomy, the tube which carries sperm from the testicles to the urethra (the tube in the penis) is cut. Once this happens, sperm can't get into the semen or out of the body. But where do they go?

Sperm are still produced by the man's testicles, but they are absorbed back into the body in a way that is harmless. The lining of the epididymis, the coiled tube behind the testes, absorbs most of the sperm, similar to if the man simply couldn't have sex for a long time. The testicles will continue to produce the male hormone testosterone, and a man's sex drive, sensation and ability to have an erection won't be affected – the only difference is that there is no sperm in the semen.

It's worth saying that this doesn't happen immediately – it can take several weeks to clear the sperm, because some stay in the tubes after the procedure. For most men, sperm will be cleared by around 12 weeks after the procedure, but contraception needs to be used until the semen is tested and found to be clear. ***NM***

HOW DOES GEOTHERMAL ENERGY PRODUCE ELECTRICITY?

In volcanic regions, reservoirs of hot underground water will rise up a borehole under their own pressure and turn into steam to drive a turbine at the surface. But in most of the world, the rocks within reach of drilling equipment are dry, impermeable rocks such as granite, so an engineered geothermal system has to be created.



1 COLD WATER PUMPED IN

Cold water is pumped at high pressure into an injection well. The water forces natural cracks in the strata to expand, allowing the water to seep sideways through the hot rock. This is similar to the fracking process used for oil and gas extraction, but doesn't require harmful solvents.

2 HOT WATER EXTRACTED

Several 'production wells' are also drilled nearby to allow the heated water to flow back out of the rock. Drilling these wells involves a certain amount of luck because they must hit one of the fissures – typically less than 5cm wide – in order to extract the water. Modern geo-imaging technology has improved the hit rate to as high as 80 per cent, compared with only 25 per cent a few years ago.

3 ELECTRICITY GENERATED

At the surface, the hot water is passed through a heat exchanger to boil a secondary fluid, such as butane, which creates high pressure gas to drive a turbine, generating electricity. The cooled water is pumped back into the rock strata in a closed loop.

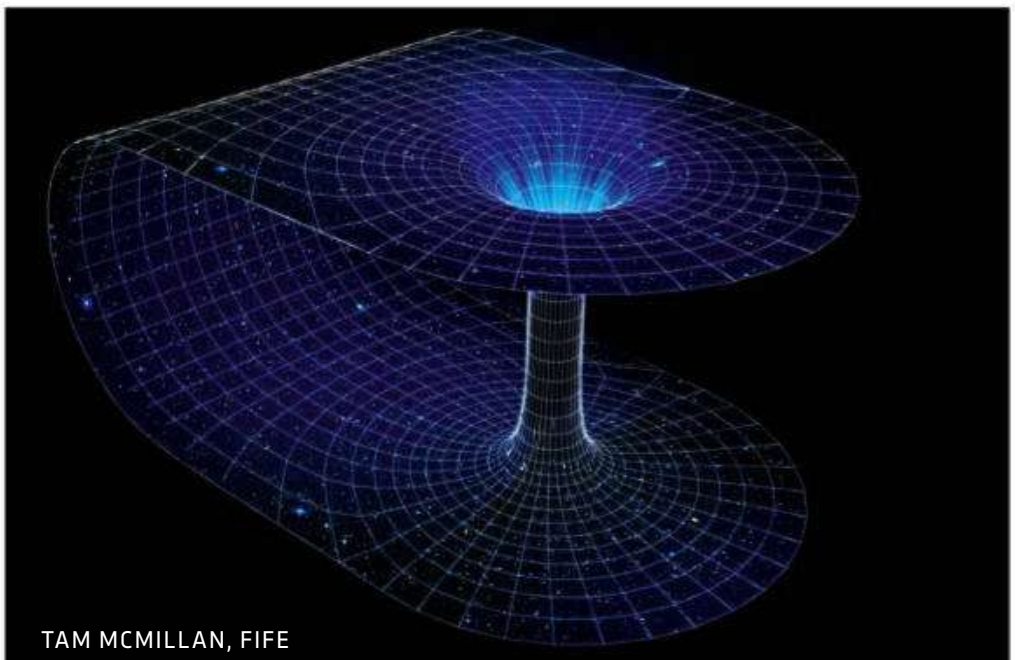
SALLY DAWES, CHESTER

ARE YOU MORE LIKELY TO GET CHEST INFECTIONS IF YOU'VE GOT NO TONSILS?

In 2018, a large study hit the press that looked at over one million Danish children, and found that there was a link between removal of the tonsils in childhood and contracting upper respiratory tract infections as an adult.

This is a tricky one, because association does not mean causation. In other words, did those children have an underlying issue with their immunity that meant they might have got more infections later anyway?

In any case, we shouldn't be operating unless we really need to, but that's always been the case – there are clear guidelines outlining when severity is bad enough to warrant surgery, and the benefits are likely to outweigh the risks. ***NM***



TAM MCMILLAN, FIFE

WHAT IS A WORMHOLE?

A 'wormhole', first proposed by Albert Einstein and Nathan Rosen in 1935, is a theoretical 'bridge' through folded space-time, which could provide a means of traversing large distances instantaneously. Mathematically, wormholes appear to be highly unstable and would likely collapse as soon as they form, as well as being vanishingly small. And they can only form with so-called 'eternal' black holes – ones which do not interact with matter or lose mass through Hawking radiation. So, most scientists would admit that wormholes, although a useful and interesting theoretical possibility, probably don't exist in reality. ***AG***

HARRY THOMAS, EASTBOURNE

ARE ELECTRIC CARS DEFINITELY GREENER THAN PETROL?

At first glance, electric cars can seem like the perfect antidote to petrol and diesel vehicles, whose fumes choke up towns and cities with air pollution. But they can still have detrimental effects on the environment.

As far as greenhouse gas emissions are concerned, electric cars are only as green as the energy used to manufacture them and to charge their batteries. However, a recent study by the International Council on Clean Transportation concluded that over their lifetime (including manufacture) electric vehicles are responsible for fewer greenhouse gas emissions than their petrol counterparts. But this difference was far greater in some places than others.

In Europe, an electric car generates up to 69 per cent less CO_2 equivalent per kilometre than a petrol car. However, in India this figure is 34 per cent. The disparity comes down to how electricity is sourced in each country. One of the lowest-carbon places in the world to charge an electric car is France, where only 9 per cent electricity comes from burning fossil fuels. But many countries still produce most of their electricity from coal, oil and gas, so plugging in an electric car in China or India can indirectly generate a large quantity of greenhouse gases.

Electric vehicles' lithium-ion batteries can be an environmental hazard if disposed of carelessly, although they are considerably less toxic than traditional lead-acid car batteries. Unlike lead-acid batteries, lithium-ion batteries are tricky to recycle and liable to explode if disassembled incorrectly. Currently only 5 per cent are recycled. Many car manufacturers, such as Tesla, are stepping up their recycling programmes, but it remains to be seen if they will be able to cope with skyrocketing demand as the electric vehicles on the road today reach the end of their lifespan. ***AFC***

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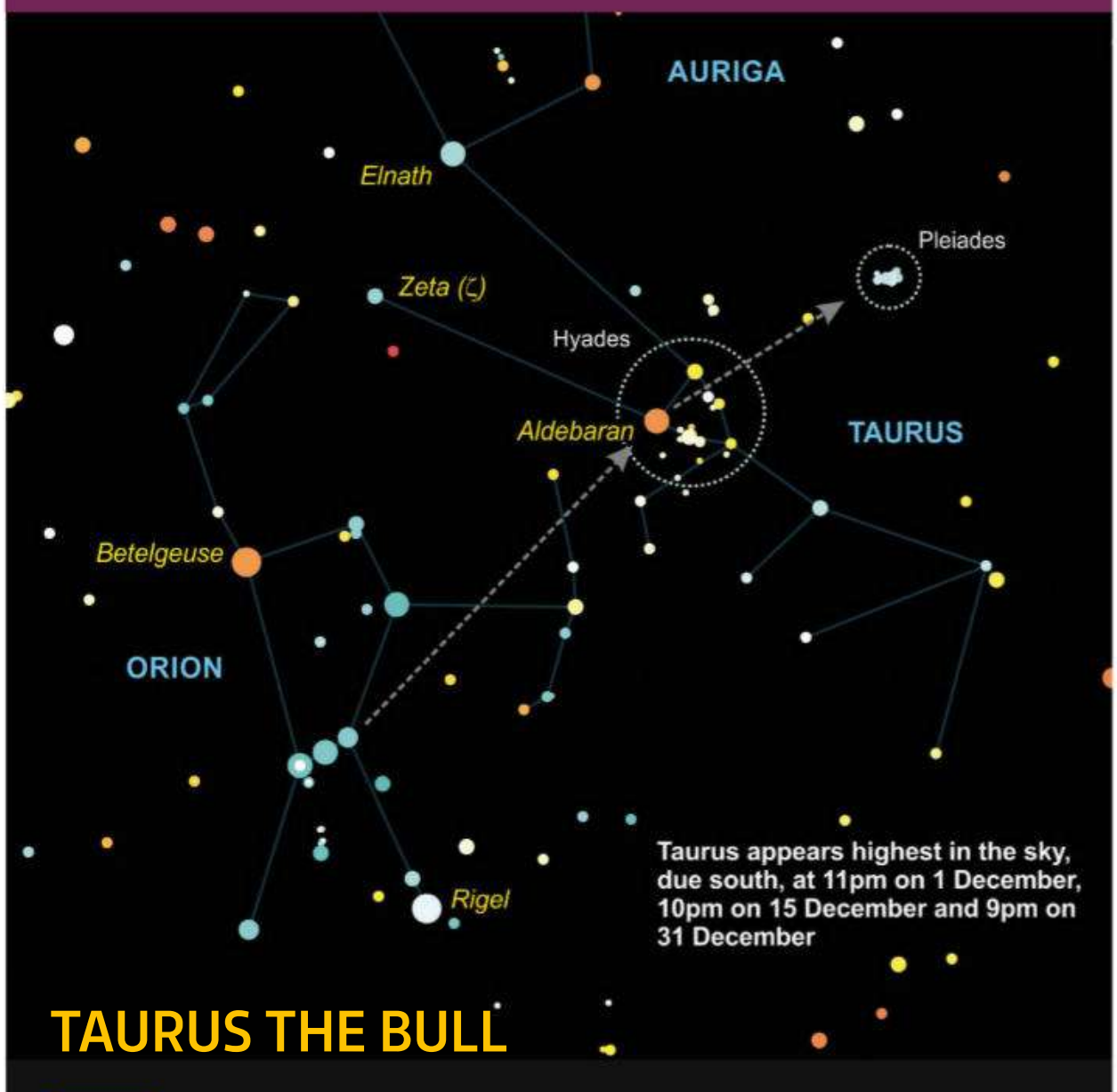
ASTRONOMY FOR BEGINNERS



TAURUS THE BULL

WHEN: LATE AUTUMN

Taurus the Bull is a prominent late autumn constellation. It outlines the head, horns and upper torso of a swimming bull, the form taken by Zeus to win the affections of a Phoenician princess.

Its primary star is the red-giant Aldebaran, the 14th brightest star in the night sky. Extend the line of Orion's belt up and right from the UK and Aldebaran is the first bright star you meet, its orange hue being very obvious.

Aldebaran lies at the end of the southern arm of a sideways V-shaped pattern of stars formed from stars in the Hyades open cluster. Born out of the same cloud of material 625 million years ago, many Hyades stars have turned reddish due to their great age. Located 153 light-years away, the Hyades is the nearest open cluster to Earth. Although Aldebaran appears part of the group, this is a line-of-sight effect. Aldebaran is 65 light-years away, positioning it roughly halfway between us and the cluster. The Hyades 'V' represents a bull's head, Aldebaran marking one of its eyes.

Extending Orion's belt line past Aldebaran eventually brings you close to the famous Pleiades open cluster, also known as the Seven Sisters. This is three times more distant than the Hyades and much younger, with an estimated age of around 100 million years. The Pleiades is distinctive, easily visible to the naked eye and a real treat through binoculars.

Extend the arms of the Hyades 'V' and eventually you'll arrive at the stars marking the bull's horn tips; Elnath to the north and Zeta Tauri to the south. Star charts often show Elnath linked to the stars of Auriga the Charioteer to the north. The star used to be known as Gamma Aurigae before being reassigned to Taurus by the International Astronomical Union in 1930. *PL*

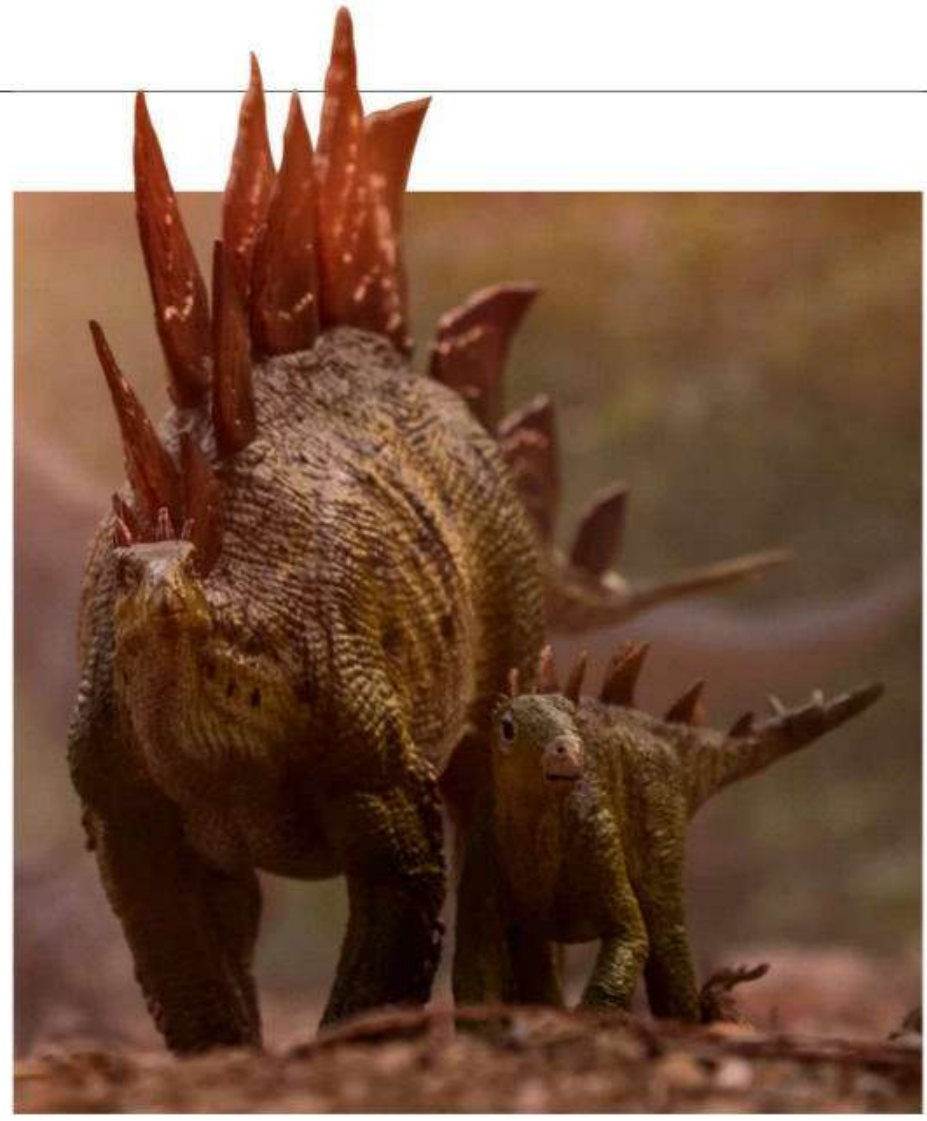
EXISTENTIAL CRISIS OF THE MONTH...

WE'RE TOO LATE TO STOP CLIMATE CHANGE

It can be hard not to be despondent about climate change. It's already impacting extreme weather events around the world, from heatwaves to hurricanes, and this impact is expected to grow as more warming gases are added to the atmosphere. We need to cut yearly global emissions roughly in half by 2030 compared to 2010 levels to stay on track to limit temperature rise to 1.5°C above pre-industrial levels, but current Paris climate pledges put us on track for emissions to be 16 per cent higher in 2030 than in 2010.

As David Attenborough said earlier this year: "no matter what we do now, it's too late to avoid climate change". So we will need to adapt to it to some extent. However, we still have plenty of scope to limit the worst impacts. Since the Paris Agreement was signed six years ago, there has been a strong shift in climate ambition. Renewables have fallen massively in price and climate change has shot up political agendas. While the latest round of Paris climate pledges this past year still fall well short, they are an improvement on pledges five years ago: they put the world on track for a 2.4°C rise by the end of the century, rather than 2.7°C. We also know we have a plethora of existing climate solutions which can rapidly cut emissions, if only we choose to use them.

And it will never be too late to stop climate change, because it will always be better to keep temperature rises as low as possible. Limiting it to 2°C is better than 2.5°C; better than both of these is keeping it below 1.5°C. *JT*



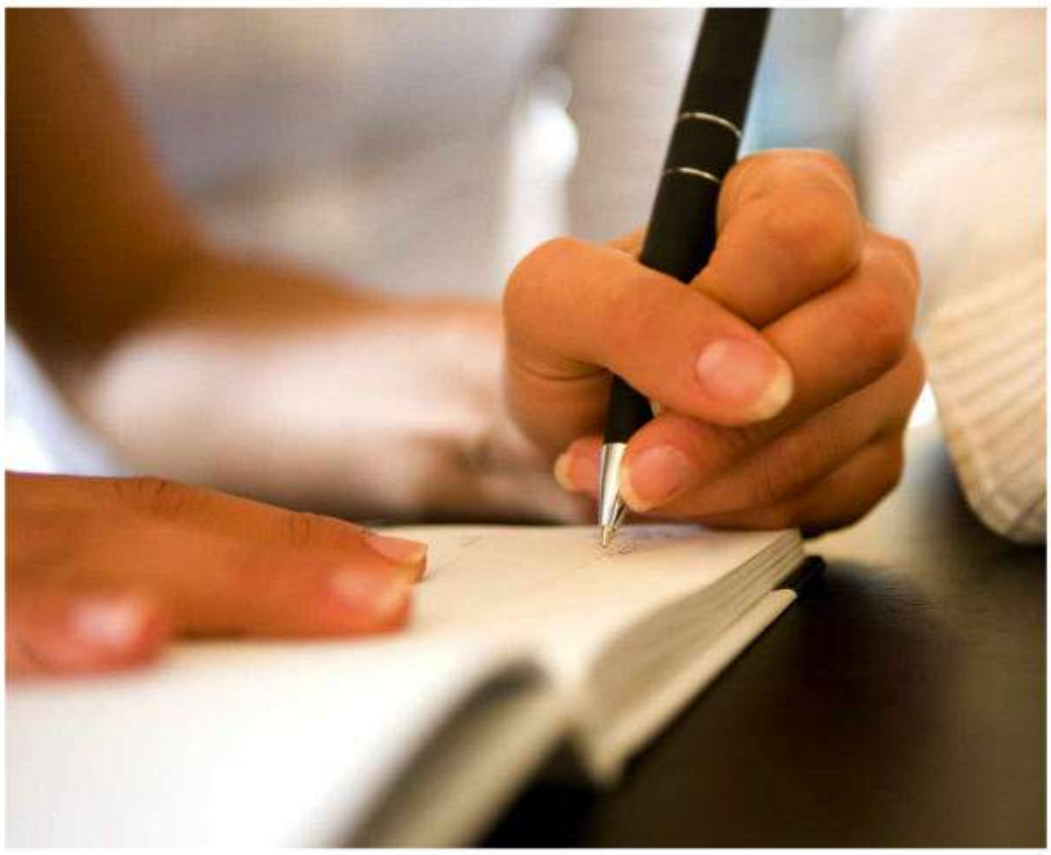
ANNA PATTON, DERBY

WHAT WERE THE SPINAL PLATES ON *STEGOSAURUS* FOR?

Stegosaurus is one of the most recognisable dinosaurs, for one main reason: the big, triangle-shaped plates lining its neck, back and tail. They are arranged in two rows of alternating pairs, and at the tip of the tail they transition into a line of foreboding spikes, each more than 30cm long. The largest plates, located over the back and hips, are the size of coffee tables. Seen in side view, *Stegosaurus* cuts a unique profile. But it is hardly alone – such plates are a defining feature of a wider group called the stegosaurs, comprised of *Stegosaurus* and its closest fossil relatives like *Kentrosaurus* and *Huayangosaurus*.

Ever since the first *Stegosaurus* skeletons were found in western North America during the 'Bone Wars' of the 1870s, palaeontologists have debated the function of the plates. One idea was that they were defensive structures – armour to fend off the bites of the hatchet-skulled apex predator *Allosaurus*. However, some questioned whether protective plating sticking up from the back, rather than guarding the flanks, would actually be effective. More recently, researchers have posited other explanations. Stegosaurs vary widely in the size, shape and distribution of their plates, which hints that they may have been used as display structures, to signify species membership, attract mates, or intimidate rivals. Histological thin sections of the plates show their outer layer is engulfed with channels for blood vessels and nerves, which may have enabled them to act as solar panels and heat dumps, to help control metabolism. However, the dense vascularisation may have simply been used to help the sheath that once covered the bony plate – made of keratin, the same stuff as our fingernails – grow rapidly or even change colour, which would be useful for display.

Although there is no firm answer, it seems display and perhaps thermoregulation are more likely functions than defence. ***SB***



JAVIER RODRÍGUEZ, MADRID

ARE THERE MORE LEFT-HANDED PEOPLE IN SOCIETIES WHERE THE WRITTEN WORD FLOWS RIGHT TO LEFT?

Quite the reverse. Various surveys have found that the highest incidence of left-handedness is in Western countries. The Netherlands, the USA and Canada lead with around 13 per cent of the population being left-handed and the UK is only just behind. The countries that use right-to-left writing systems are predominantly Arab and Asian and they all have left-handedness rates below 6 per cent. In Muslim countries, the advantage of smudge-free handwriting is outweighed by the fact that the left hand is considered unclean. Writing, eating and shaking hands is all done with the right hand and naturally left-handed children are taught to use their right hands for these tasks from an early age. ***LV***

QUESTION OF THE MONTH

KOBY SHOMRON

WHY DO WATER DROPLETS REMAIN ON PLASTIC ITEMS AFTER THEY'VE GONE IN THE DISHWASHER?

Dishwashers work by spraying jets of water and detergent at up to 68°C – much hotter than you would use for washing up by hand. At the end of the washing cycle, the hot, clean crockery dries itself just by evaporation. But although everything inside the dishwasher starts off at the same temperature, plastic items cool down much quicker. This is because they have lower 'thermal mass'. The plastic of a food storage container is thinner than a cup or plate, and plastic is a lower density material, so for a given temperature, its molecules hold less heat energy. As the water evaporates from the surface, it quickly cools the plastic down and this slows the rate of evaporation. Heavy plates and pans hold their heat much longer and are still quite warm even after all the water has been evaporated away. China, glass and metal are also much better heat conductors than plastic. This means that all the heat in the vertical sides of an upturned bowl or cup can flow quickly to supply heat to the horizontal surfaces, to evaporate any water that has puddled. The heat in a plastic container spreads more slowly so small water droplets remain on the surfaces. ***LV***

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WINNER

The winner of next issue's *Question Of The Month* wins a **shortlist of books from the Royal Society Book Prize,** worth £67.96. The prize includes *The Last Stargazers: The Enduring Story Of Astronomy's Vanishing Explorers; Breath: The New Science Of A Lost Art; The End Of Bias: How We Change Our Minds; The Sleeping Beauties And Other Stories Of Mystery Illness; Science Fictions: Exposing Fraud, Bias, Negligence And Hype In Science and Entangled Life: How Fungi Make Our Worlds, Change Our Minds And Shape Our Futures.*
royalsociety.org

EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM**

THE EXPLAINER

BLUE LIGHT

WHAT IS BLUE LIGHT?

The Sun bathes us daily in light, which is one of many types of electromagnetic radiation, along with radio waves, microwaves and gamma rays. We can't see the vast majority of these energy waves flowing through space, but we can measure them. The light that human eyes can see, as it bounces off objects, has wavelengths of between 380 and 700 nanometres. Within this spectrum, running from violet to red, blue light vibrates with almost the lowest wavelength (400 to 450nm) but almost the highest energy.

There couldn't be anything more ordinary than blue light. It's the reason the sky looks blue – because it bounces off the molecules in the Earth's atmosphere more readily than the rest of the visible light spectrum. Most of us weren't particularly aware of blue light until manufacturers discovered the quality with which blue-light-heavy LED technology can produce light and colour, with supreme efficiency in both power and size – ideal for electronic lighting and smart devices. Now that these devices have become our interface with the world, many of us stare at blue light all day, and long after the Sun goes down.

IS BLUE LIGHT RUINING MY SLEEP?

It depends. A daytime stroll, which will expose you to significantly more blue light from the Sun than any human-made device, can help ensure you get a good night's sleep. Being exposed to bright sunlight helps maintain a healthy circadian rhythm, which regulates sleep and alertness, along with other biological processes such as appetite and digestion. A study published in the journal *Sleep Health* in 2017 found that workers exposed to more morning sunlight slept better than those that saw less light, and they also felt less depressed and stressed.

But just as not having enough daytime light can lower our sleep prospects, so can too much blue light in the evening. This is because our circadian system, which evolved when we lived largely outside with no electricity, is regulated by light cues received by our eyes. We've long known that our visual photoreceptors, known as rods (for night sight) and cones (for bright light and colour) do this to some extent. But only in the 21st Century did we discover that we also have photosensitive retinal ganglion cells, which act as light meters that set our circadian responses. These are particularly sensitive to blue light. Other frequencies on the visual light spectrum can, even without blue light, trigger the circadian system (the brighter the light, the greater the effect), but not as readily.

In 2017, researchers at the University of Haifa, Israel, found that exposure to blue light in the evening, on average, reduced duration of sleep by 16 minutes. It also reduced production of melatonin, a hormone that influences the circadian rhythm.

So dim your lights in the evenings and set your gadgets to night-mode, or turn down their brightness. Sleep experts routinely advise switching off devices an hour before bed.

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DO BLUE LIGHT GLASSES WORK?

Anything that promises relief from tired eyes is sorely tempting. Glasses that block blue light promise to improve sleep, prevent eyestrain and dry eyes, and even enhance vision clarity, but the research is inconclusive. In 2017, Boots Opticians was forced to withdraw advertising for their anti-blue-light glasses, which cost £70 and were found to filter only 20 per cent of blue light. The Advertising Standards Authority ruled that not only had Boots exaggerated the protection the glasses would provide, but also the threat of blue light from digital devices (Boots had cited retinal damage).

CAN TOO MUCH BLUE LIGHT DAMAGE MY EYES?

With the great outdoors providing by far our most extreme exposure to blue light, we'd know by now if blue light was a problem. That said, staring at low-level blue-dominant light, unblinkingly, for the majority of our waking hours, is a relatively new phenomenon, and digital eyestrain is a common complaint. So far there's no evidence that blue light from devices is a culprit. Computer users tend to blink five times less than usual, which could result in dry eyes. And focusing on anything for long periods without a break is a recipe for tired eyes. You can damage a retina if you point strong blue light at it for long enough, which is why we don't look directly at the Sun, or LED torches.

WHY IS BLUE LIGHT USED BY SOME DOCTORS?

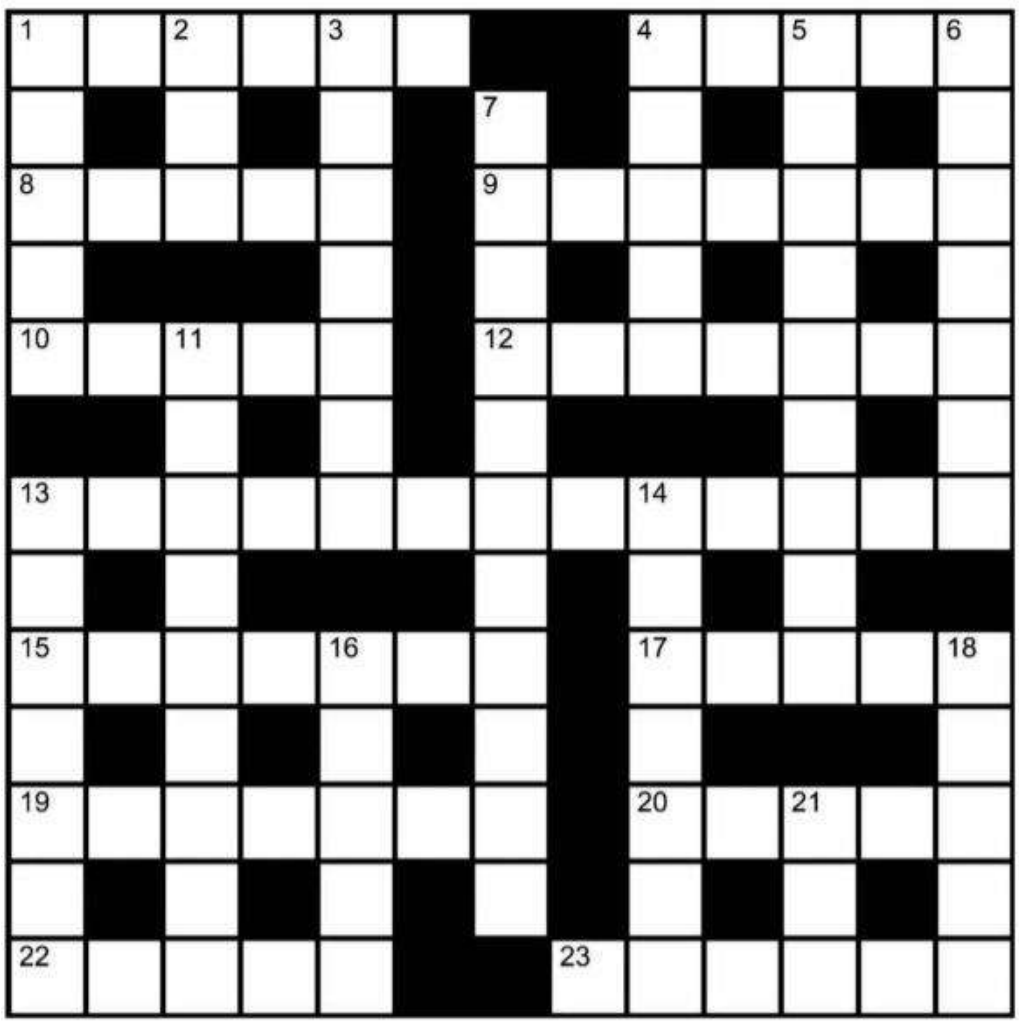
Despite its recent bad press, blue light has medicinal applications. The lamps used to treat Seasonal Affective Disorder (SAD) concentrate blue light at its highest-energy wavelengths to mimic sunlight. One study at the Mood Disorders Clinic at the University of Utah in 2009 found that 60 per cent of participants' depression improved after three weeks of the therapy. Blue light wakes us up, and it is thought that the therapy stimulates melatonin and serotonin production.

Blue light has also been used to effectively treat inflammatory skin conditions, such as psoriasis and atopic dermatitis. Conventional UV light therapy comes with increased risks of skin cancer and skin ageing, but studies now imply that high-energy blue light has a similar dampening effect on the skin's immune response, reducing inflammation without the side effects.

by **AMY FLEMING**
Amy is a freelance writer and former Guardian *staff journalist.*

CROSSWORD

PENCILS AT THE READY!



ACROSS

1 Picture small boat (6)
4 Imagine daughter getting a lot of paper (5)
8 Inclined to have meagre time (5)
9 Weapon had set out as a carved ornament (7)
10 Attorney takes sheep to a play (5)
12 Captive has got terrible English (7)
13 Making pencil useless at toughest moment (8,5)
15 Critical terror halved, initially, in animal (7)
17 Calling out about jargon (5)
19 Footwear for idle people (7)
20 Time for some music (5)
22 Feed injury (5)
23 One insect let off another (6)

DOWN

1 Food as ordered by boy (5)
2 Time of underachievement (3)
3 Pet decree returned to king in a fashionable way (7)
4 Fruit days (5)
5 Cautioned about tuition (9)
6 Mother opposing directions for film star (3,4)
7 Magician broadcast hen's trances (11)
11 Yank on a bunch of collectibles (9)
13 Returned to record what still needs to be done (7)
14 Range of colours is allowed and spread outside (7)
16 Three ran to that place (5)
18 Gas round area of land (5)
21 Claim a tenant concealed a rug (3)

ANSWERS For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

NEXT ISSUE

2021 IN IMAGES

GETTY IMAGES

PLUS

ALIEN LIFE IN OUR SOLAR SYSTEM

Next year, the JUICE mission blasts off on its journey to study the moons of Jupiter. What might it find on these icy worlds?

ROBOT TRUCK DRIVERS

Could they come to a motorway near you?

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SF

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POPCORN SCIENCE

Are we living in a simulation?

Don your black leather and a pair of shades, it's time to take a trip into the Matrix

by **STEPHEN KELLY**

It has been 22 years since *The Matrix* popularised the idea that reality is an illusion and that we are all actually lying in pods of fluid, serving as nutrients for machines. It sounds fantastical to most people – typical science fiction – but there are certain scientists and philosophers who believe that *The Matrix*, along with the long-awaited sequel *The Matrix Resurrections*, raises some serious questions of whether we really are living in a computer simulation. So, are we? You take the blue pill and the article ends. You close the magazine and go back to descaling the kettle. You take the red pill and you keep on reading and Rizwan Virk, computer scientist and author of *The Simulation Hypothesis*, will show you how deep the rabbit hole goes.

"I think it's more likely than not that we are in some kind of simulation," says Virk, whose book is built upon a 2003 paper by Oxford philosopher Nick Bostrom that asks whether we are living in a computer simulation. It argues that the most probable outcome, among three options, is that an advanced civilisation will survive long enough to be able to develop the technology to create various simulated worlds. "This means that there are many simulated realities and there's only one base reality," explains Virk. "Therefore, which reality are you most likely to be in – the 99 simulated realities or the one base reality? You're more likely to be in the 99."

It's a theory that is yet to be proved, but it hasn't been disproved either. One of Virk's big arguments is based on physicist John Wheeler's phrase 'it from bit', the idea that the basis of the Universe is not energy or matter but information, with each subatomic particle representing a bit. "We can basically 3D print any object, and genes are just data," says Virk. This feeds into his larger argument that if the multiverse – the hypothesis that every time a decision is made, it creates a new timeline – is real, it backs up the premise that reality is digital rather than physical. "There's nothing in nature that duplicates an entire large physical object, particularly in an instant," he says, "but it is pretty easy to duplicate information and then render that information as needed."

He also cites the observer effect, a phenomenon in physics in which the mere act of watching something can change it. "That doesn't make sense if you live in a single physical reality," says Virk, "but in video games we only render the world when you need to see it. That suggests we live in a rendered world, where reality only exists when it is observed."

Let's say it's true, let's say that we are all living in a computer simulation: who or what is on the other side? "Some people say it's aliens," says Virk. "In Bostrom's simulation argument, the simulations are what he calls 'ancestor simulations' conducted by future versions of ourselves. It would basically be like us simulating ancient Rome." And why would they want to run a simulation of our world? "Well, why do we run simulations? Usually it's to figure out different possible outcomes. We might run a simulation of, say, global nuclear war or climate change. We might run it multiple times to see what scenarios are more likely to lead to destruction."

But if we live in a computer simulation, then how does that affect our approach to life? Doesn't it make everything meaningless?

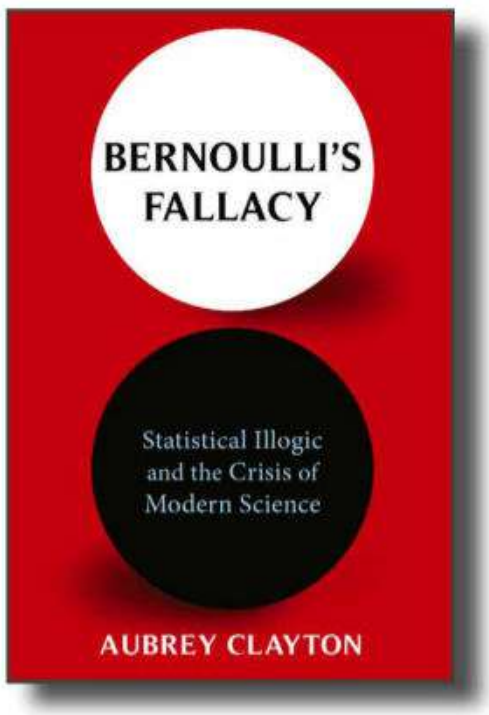
"Some people say, 'well, it doesn't matter what you do'. For me, it's not quite that," explains Virk. "It's more that I've chosen to play this game, I've chosen some of its quests and challenges. And it wouldn't be a very interesting game if everything was easy." **SF**

VERDICT
The simulation theory is sound, and we love Keanu Reeves, so it looks like we'd better take the red pill.

by **STEPHEN KELLY** *(@StephenPKelly)*
Stephen is a culture and science writer, specialising in television and film.

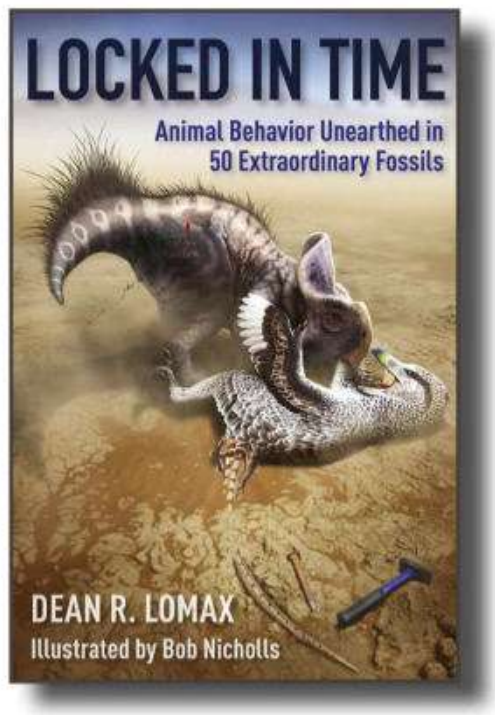
ILLUSTRATIONS: ADAM GALE MAIN ILLUSTRATION: CHRISTINA KALLI

NEW SCIENCE TITLES FROM COLUMBIA UNIVERSITY PRESS



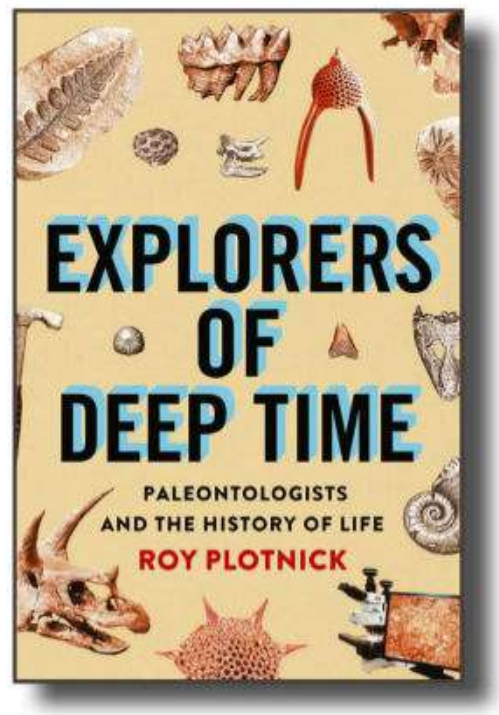
"Anything that gets people thinking about the uses and abuses of statistics is important and Clayton's book does just this."

—Persi Diaconis, Stanford University



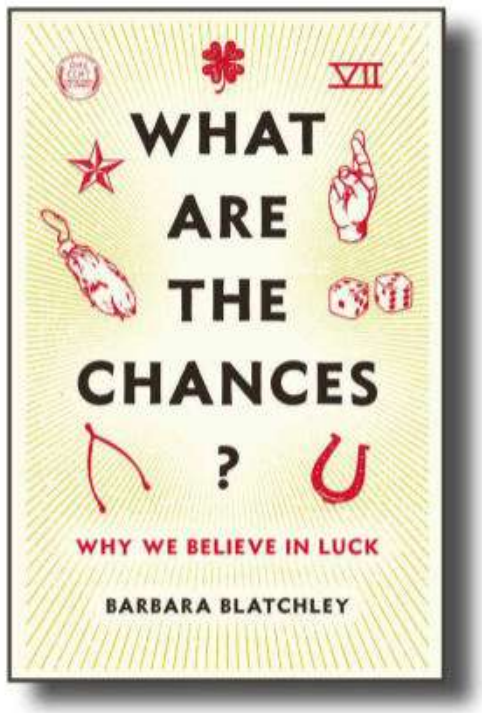
"A rousing romp through the fossil record. Dean R. Lomax's storytelling and Bob Nicholls's artwork reanimate the lifestyles and behaviors of long-extinct species. Revel along as old bones, teeth, and footprints tell the tale of dinosaur mating dances, fighting mammoths, and pterodactyl nurseries."

—Steve Brusatte, *New York Times* best-selling author of *The Rise and Fall of the Dinosaurs*



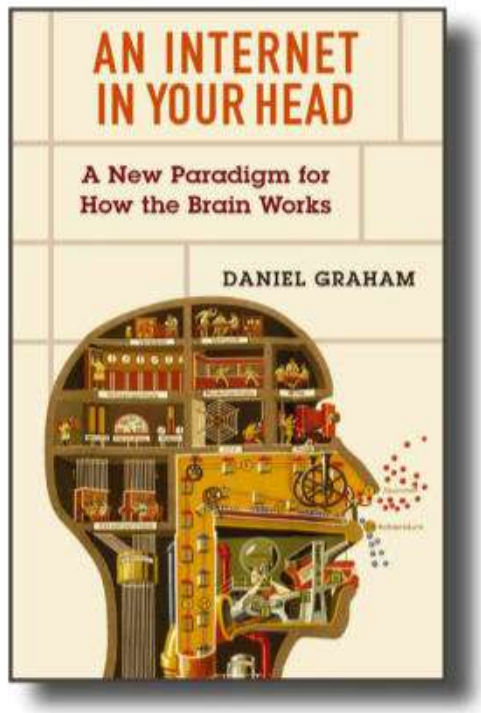
"Plotnick has gone above and beyond to highlight as many of paleontology's contributors as possible, demonstrating that it is an increasingly inclusive, diverse field of study. [The book] is an invaluable tool for the budding scientist and a beautiful homage to the breadth and depth of this discipline."

—Emily Graslie,
host of *Prehistoric Road Trip* on PBS



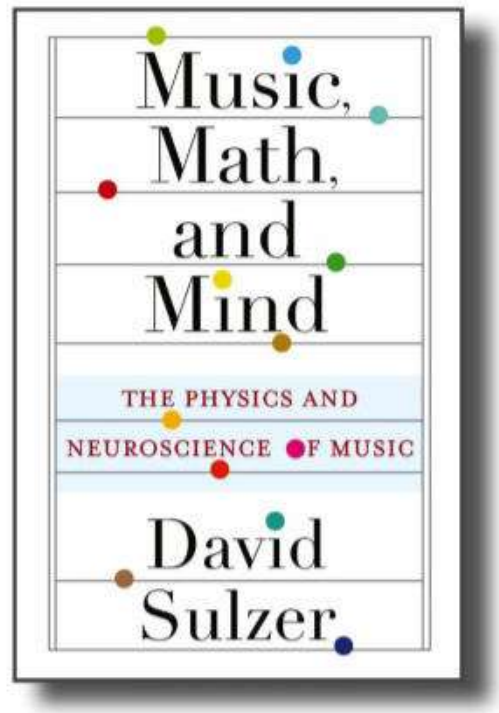
"Barbara Blatchley provides a colorful and accessible look at the fascinating nature of luck. Focusing on the human side as well as the neuroscientific and psychological aspects, she explores what luck is and the role luck plays in our lives."

—David Hand, Imperial College London,
author of *The Improbability Principle*



"A fresh, insightful, and informative perspective on brain function, proposing that communication between neurons resembles signal passing in the internet as a novel metaphor to investigate the brain. [Graham] provides erudite discussions and presents compelling arguments in a lively and clear manner."

—Gabriel Kreiman, Harvard Medical School



"Here is the place to find out about the way crickets make music, and the McGurk effect! The science comes along gently, never intimidating. Only a neurobiologist who is a master composer and musician could have written this wonderful book!"

—Roald Hoffmann,
author and recipient of the Nobel Prize in Chemistry

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